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Reconnaissance Study of Final Cut Impoundments

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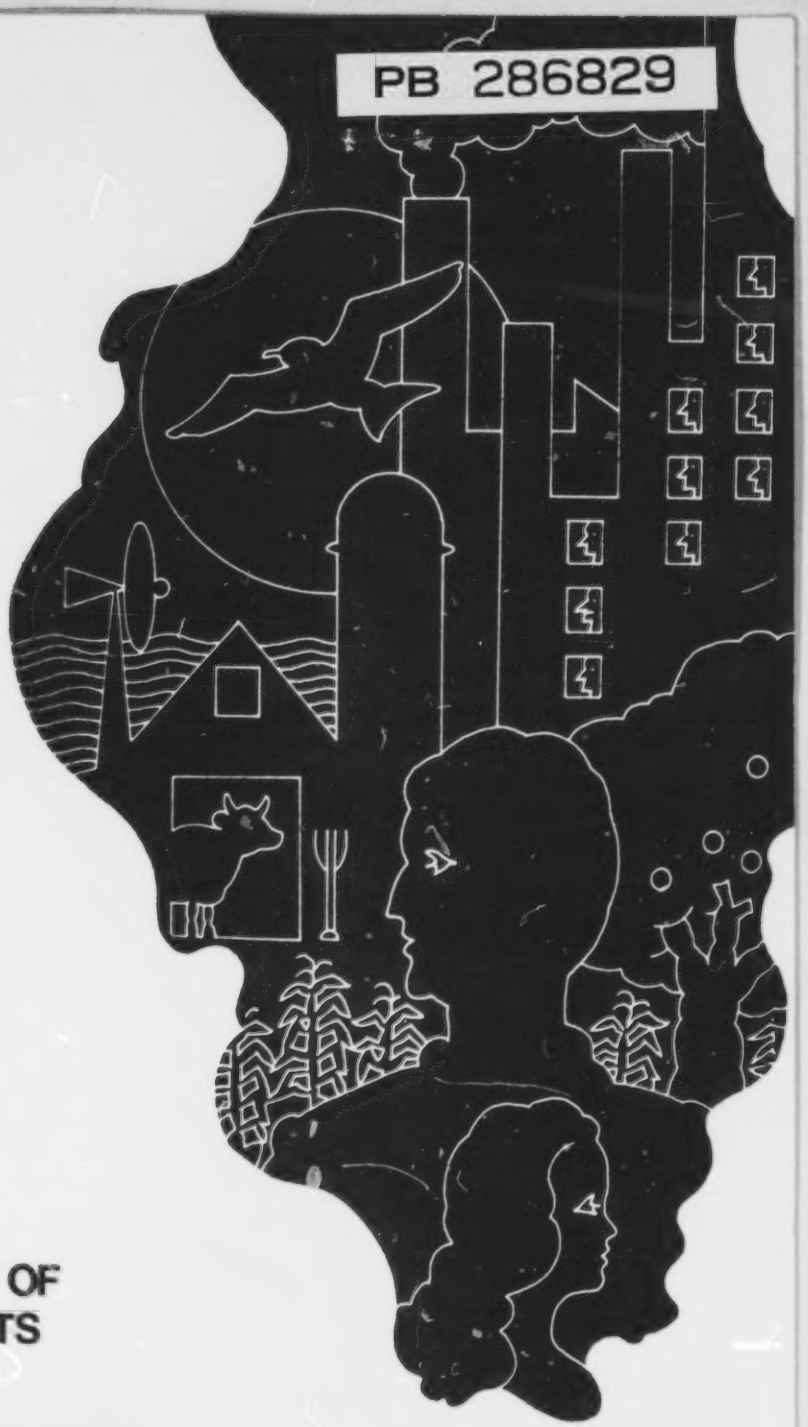

RECONNAISSANCE STUDY OF FINAL CUT IMPOUNDMENTS

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by

James P. Gibb
Associate Engineer

and

Ralph L. Evans
Head, Water Quality Section
Illinois State Water Survey
Urbana, Illinois 61801

PROJECT OFFICER: Marie Lauricella
Project No. 80.096

Frank Beal, Director
State of Illinois
Institute for Environmental Quality
309 West Washington Street
Chicago, Illinois 60606

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Illinois Institute for Environmental Quality
309 West Washington Street
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(312) 793-3870

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Field measurements and calculations of lake volumes and yields were made by William C. Bogner, Assistant Hydrologist, with the assistance of Steve Wirth and Ken Smith, Hydrology Assistants. Water quality measurements and samples were collected by Donald Roseboom and Tom Hill, Assistant Biologists, and Jack Williams, Technical Assistant. Analyses of water samples were conducted at the Peoria and Urbana laboratories of the Illinois State Water Survey.

The project was conducted under the general supervision of John B. Stall, Engineer Emeritus and former Head of Hydrology, and Richard J. Schicht, Head of Hydrology, Illinois State Water Survey. Schicht also reviewed the final manuscript. The art work was prepared by June Blake and William Motherway, Jr. The draft and final manuscripts were typed by Diane Stelter and Janny Travers. J. Loreena Ivens and Patricia A. Motherway edited the final report, and Diane Stelter prepared the camera copy.

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ABSTRACT

Twelve representative final cut impoundments were selected and studied to determine their volumes and estimated yield potentials. The volumes range from 97 to 3488 acre-feet and average 812 acre-feet. Estimated yield potentials at a 2-year recurrence interval range from 0.15 to 3.98 million gallons per day and average 0.86 million gallons per day. Projections of these estimates to lakes inventoried through June 30, 1971, were made and presented as county totals. The potential water supply from final cut impoundments for the 40 surface mining counties in Illinois range from 0 to 75.66 mgd. For 10 counties the estimated yield potential from final cut impoundments exceeds the estimated 2020 water demands.

Based on published water quality requirements and data collected during this study, only 2 of the 12 lakes studied have water quality suitable as a source for public water supply. Three are suitable for irrigation and all 12 are suitable for livestock watering. However, the quality of water from these impoundments is treatable and often comparable to the quality of alternative water sources. Each lake should be evaluated more closely in terms of yield, quality, and the economics of development as compared with other available water resources.

INTRODUCTION

The first commercial surface coal mine in the United States was opened near Danville, Illinois, in 1866. Horsedrawn scrapers were used to remove shallow overburden materials and the underlying coal (1). The development of a large steam-powered stripping shovel in 1911, followed by continued development of larger and more efficient equipment, has greatly expanded the surface mining industry (2). Surface mining now is a major method used in producing the nation's coal needs. In 1977, coal production in Illinois totaled approximately 53.9 million tons, of which about 45 percent (24.3 million tons) was from surface mining (preliminary figures from the Illinois Department of Mines and Minerals).

Surface mining for coal in Illinois occurs in 40 counties (see figure 1). Strippable bituminous coal reserves (coal seams at least 18 inches thick and less than 150 feet below land surface) are the largest in the United States (3). Excluding two areas not yet mapped, Simon and Smith (3) reported an estimated 19 billion tons underlying 2.3 million acres of Illinois land.

As of June 30, 1971, a total of 163,643 acres (only 7 percent of the potential strippable area) of Illinois land had been surface mined for coal. Twelve counties contained 90 percent of the mined acreage: Fulton 40,524; Perry 20,317; Knox 17,350; Williamson 12,701; St. Clair 12,482; Saline 9504; Grundy 7134; Peoria 6187; Will 6067; Randolph 5425; Vermilion 5297; and Jackson 4899 acres (4).

Water on surface-mined lands totaled 14,243 acres of which 12,149

Figure 1. Surface mining counties in Illinois and selected lakes.

acres are lakes developed in abandoned pits resulting from the final cut and the haulage roads (4).

There is extensive literature concerning strip mining of coal in Illinois. Most reports discuss the coal reserves suitable for surface mining, the reclamation of land after mining, and acid drainage problems resulting from mine activities. Recreational use of strip-mined lands and their waters also has received considerable attention. However, very little work has been done to better understand the hydrology of strip-mined lands or to evaluate the potential resource of the water bodies contained in strip-mined areas.

Federal legislation in the Coal Surface Mine Regulation Act now requires that strip mine impoundments or water bodies be filled. This action has alerted officials in the state of Illinois to the fact that the potential resources offered by these lakes may be destroyed. Personnel of the Department of Mines and Minerals particularly were concerned and supportive of a study of these potential resources. Because so little is known of the character of final cut impoundments this reconnaissance-type investigation was undertaken. The purpose of the study was to evaluate the usefulness of final cut impoundments for public water supply, irrigation, and other consumptive uses.

Four general study areas, Grundy, St. Clair, Fulton, and Perry Counties were selected. In each study area, 3 lakes of representative size and geologic-hydrologic setting were chosen for detailed study. Each lake was surveyed to determine its area and capacity. An estimate of the sustained yield of each lake also was made. Water samples for chemical

analysis were collected from each lake at three time intervals to determine the chemical, physical, and biological quality of the water as it relates to the proposed uses.

On the basis of results of the sample lake studies and available maps of all lakes in the 40 counties where surface mining exists, estimates of the water resource from final cut impoundments were made. A general inventory of other water resources and projected needs for these counties also is presented. The potential uses of final cut lakes are discussed from the basis of water quality, quantity available, and the estimated needs of the area.

Recommendations concerning further study of final cut impoundments also are made.

PHYSICAL FEATURES OF THE LAKES

Lake Selection

During September 1977, well over 100 strip mine lakes were observed from the air and approximately 60 were visited for closer examination. Lakes of representative sizes and shapes initially were selected from the air. During field examinations, final selections were made on the basis of access to the lakes, proximity to other water bodies or courses into which water could be pumped, and the cooperativeness of the property owners on which the lakes are located. Twelve lakes finally were chosen at locations indicated on figure 1 and table 1.

Table 1. Selected Final Cut Impoundments

Number	*Name*	*Owner*	*Location*
1	Middle Grove	Peabody Coal Co.	Sec 19, T9N, R4E,[a] Knox County
2	Sunspot West	Amax Coal Co.	Sec 9 & 10, T3N, R1E, Fulton County
3	Sunspot East	Amax Coal Co.	Sec 6, T3N, R2E, Fulton County
4	Pinckneyville No. 2	Consolidated Coal Co.	Sec 17, T5s, R2W, Perry County
5	Old DuQuoin Pit	Consolidated Coal Co.	Sec 6, T5S, R2W, Perry County
6	"East C" Streamline	Southwestern Coal Co.	Sec 32, T5S, R4W, Randolph County
7	Red Ray	Peabody Coal Co.	Sec 33, T1S, R7W, St. Clair County
8	Seminole	Peabody Coal Co.	Sec 2, T3S, R7W, St. Clair County
9	River King No. 6	Peabody Coal Co.	Sec 28, T3S, R6W, St. Clair County
10	Coal City Area No. 1	Coal City Sportsman Club	Sec 31 & 32, T33N, R9E, Will County
11	Clear Lake	South Wilmington Sportsman Club	Sec 5, T31N, R9E, Kankakee County
12	Northern Pit No. 14	Peabody Coal Co.	Sec 13, T31N, R8E, Grundy County

[a]Abbreviated for Section 19, Township 9 North, Range 4 East

Two of the selected lakes, Pinckneyville No. 2 (lake 4) and "East C" Streamline (lake 6), were still in the process of filling after the conclusion of mining. It was hoped that data collected on these lakes would prove useful in determining the yield capabilities of these lakes.

Volume and Area Determinations

Aerial photographs were obtained for each lake to determine surface areas and to select the locations of range lines along which depth measurements were to be made. Depth measurements were taken along each range line at 50 foot intervals using a Lowrance model LFG 360 depth sounder. This sounding device operates on sonar principles at a frequency of 192 kilohertz. The transducer emits a 22-degree signal resulting in a 12 foot diameter circle at a depth of 30 feet. Proper reading of the dial and suppression of false signals permitted obtaining depth measurements within 1 foot of mechanically measured depths.

The six lakes in the southern part of the state (lakes 4-9) were measured in the fall of 1977 from a boat during periods of open water. A marked polyethylene cable was used to determine the horizontal spacings of readings along the range line. The lakes located in western and northern Illinois (lakes 1-3 and 10-12) were measured during the winter months through ice ranging in thickness from about 6 to 18 inches. The horizontal spacings of readings along these range lines were determined by using a steel tape. At the time of each lake survey the water level of the lake above mean sea level was determined by running a line of levels from the nearest U. S. Geological Survey bench mark.

After the depth measurements were completed, cross-sectional profiles for each range line were plotted. Representative profiles for each lake are presented in the Appendix of Lake Summaries in this report. Lake volumes were calculated by the average end area method. Volume and area calculations at various water level stages permitted the development of stage-volume and stage-area curves for each lake.

Yield Determinations

Groundwater Yields

In the original study proposal, it was planned that several lakes would be pumped and the recovery rates after pumping would be monitored to determine the yield capability of each lake. It also was planned that piezometers would be installed at each lake that was pumped to allow for analysis of the surrounding groundwater regime. After determining the costs associated with pumping the large amounts of water required to lower the lake levels just 2 feet, it was decided to attempt to pump only 1 lake and install piezometers in the spoil material surrounding it. Peabody Coal Company offered their assistance and the use of one of their pumps at the Middle Grove lake, and it was chosen to be pumped. The data gathered from that work are also given in the Lake Summaries Appendix. Water balance analyses of the data showed groundwater contributions to the lake varying from about 200 to 500 gallons per minute (gpm) during the pumping test. In general, the larger values were experienced during the early stages of the test. Small errors in reading lake levels from the staff gage due to wave action on the lake were particularly sensitive during this period. Immediately after the pumping test, during a period of no

rain, analysis of lake level recovery data indicated groundwater contributions to the lake at about 200 gallons per minute.

Two other lakes (Pinckneyville No. 2 and "East C" Streamline) were selected for study because data were available describing the rates they filled after the mines closed. Two years of data existed for the "East C" lake and the Pinckneyville pit was just in the process of filling and could be monitored. The pumping attempts and monitoring of lakes while filling both were designed to obtain information on the groundwater contribution capabilities of the spoil materials surrounding these lakes. Water balance analyses of the data for the "East C" and Pinckneyville lakes proved to be instructive but did not provide the answers desired. The results of the water balance analysis for the two lakes are presented in the Lake Summaries.

Several factors influence the groundwater contribution capabilities of strip mine spoil. The character of the premining overburden, the ratio of drift materials to underlying rock overburden, the method of handling the materials, the equipment used, and the age of the spoil all affect the final hydrologic character of strip mine spoil. In dragline operations (commonly used in Illinois), spoil from the dragline is cast into the preceding trench in a series of intersecting cones. The bucket is dumped at one point until a large cone is built up. The bucket then moves back several feet and continues operating, casting materials onto the side of the previous pile, creating a long continuous spoil pile with cone-shaped peaks.

This handling procedure promotes the formation of a gravity-sorted rubble layer. The larger spoil fragments that have been fractured and broken by blasting and handling tend to roll to the bottom of the pile forming a coarse-grained rubble base (5). The formation of such a basal layer has been noted in mining operations in southern Illinois where limestone and consolidated shale are common in the overburden materials. In western and northern Illinois the overburden materials are primarily drift and soft fissel shale and this phenomenon usually does not occur.

Because of the various factors that can affect the hydrologic character of spoil materials, groundwater data from one strip mine area are not transferable to other areas. In this study, it is fortunate that the lake chosen for the pumping test is located in an area where the overburden materials were drift and soft fissel shale. The resulting spoil material therefore is likely to be among the least permeable in the state. Groundwater yield data obtained at this lake therefore should be conservative when applied to lakes in more permeable geologic settings. To estimate lake yields at all sites studied, 200 gpm ÷ 5500 feet (the length of the Middle Grove lake) or 0.036 gpm per foot of lake was used.

Surface Yields

To estimate the surface water yield of the lakes studied, runoff from the individual watersheds and an estimate of lake evaporation were considered. The U. S. Soil Conservation Service (SCS) method for determining runoff from small agricultural watersheds was used to estimate runoff (6).

The relationship developed by the SCS is:

$$Q_r = [(P - 0.2S)^2] / (P + 0.8S)$$

where:

Q_r = actual runoff, inches

P = total rainfall, inches

S = potential infiltration, inches

To apply this empirical method, the parameter CN (runoff curve number or hydrologic soil-cover complex number) was developed where:

$$CN = 1000 / (S + 10)$$

or

$$S = (1000 / CN) - 10$$

Tables of CN values have been collated by the users of this method and are summarized in table 2. However, little work has been done on the direct runoff properties of strip mine lands. Therefore, it was necessary to instrument at least one watershed to determine a reasonable CN value.

The watershed of the Middle Grove lake consists totally of spoil material planted in alfalfa. The spoil has been reshaped and is relatively flat compared with others in Illinois. A recording rain gage and water level recorder for the lake were installed. Data from these instruments were analyzed by water budget techniques and the U. S. Soil Conservation Service method. The resulting curve number for the Middle Grove lake is about 64 (see Lake Summaries Appendix for data). This value is based on 2 individual rainfall events that occurred during the period after the pumping test was completed.

Table 2. Runoff Curve Numbers for Hydrologic Soil-Cover Complexes[a]

Land use or cover	*Treatment or practice*	*Hydrologic condition*	*Hydrologic soil group* A	B	C	D
Fallow	Straight row	Poor	77	86	91	94
Row crops	Straight row	Poor	72	81	88	91
	Straight row	Good	67	78	85	89
	Contoured	Poor	70	79	84	88
	Contoured	Good	65	75	82	86
	Contoured and terraced	Poor	66	74	80	82
	Contoured and terraced	Good	62	71	78	81
Small grain	Straight row	Poor	65	76	84	88
	Straight row	Good	63	75	83	87
	Contoured	Poor	63	74	82	85
	Contoured	Good	61	73	81	84
	Contoured and terraced	Poor	61	72	79	82
	Contoured and terraced	Good	59	70	78	81
Close-seeded legumes[b] or rotation meadow	Straight row	Poor	66	77	85	89
	Straight row	Good	58	72	81	85
	Contoured	Poor	64	75	83	85
	Contoured	Good	55	69	78	83
	Contoured and terraced	Poor	63	73	80	83
	Contoured and terraced	Good	51	67	76	80
Pasture or range		Poor	68	79	86	89
		Fair	49	69	79	84
		Good	39	61	74	80
	Contoured	Poor	47	67	81	88
	Contoured	Fair	25	59	75	83
	Contoured	Good	6	35	70	79
Meadow (Permanent)		Good	30	58	71	78
Woodlands (farm woodlots)		Poor	45	66	77	83
		Fair	36	60	73	79
		Good	25	55	70	77
Farmsteads			59	74	82	86
Roads, dirt[c]			72	82	87	89
Roads, hard-surface			74	84	90	92

[a]From U. S. Soil Conservation Service (6)
[b]Close-drilled or broadcast
[c]Including right-of-way

To predict the net surface water yield of each lake on a frequency basis, 20 years of monthly precipitation data from nearby precipitation gaging stations were used. To compensate for the use of monthly rainfall totals instead of individual events, the curve number for the Middle Grove

lake was adjusted downward to 60. Curve numbers for the other lakes were chosen on the basis of the relative condition of each watershed as compared with that at Middle Grove. The percentages of farm land and spoil and the condition of the spoil were considered in selecting the final curve numbers.

Net surface water yields for each lake were calculated for the years 1958 through 1977 by applying the average monthly lake evaporation to each month's calculated runoff. Monthly evaporation rates for each lake were taken directly from state maps presented by Roberts and Stall (7). Net annual runoff totals were ranked and the values exceeded 90, 50, 20, and 10 percent of the time are presented for each lake. These values correspond to recurrence intervals of 1.1, 2, 5, and 10 years, respectively.

Summary of Lake Physical Features

A summary of the physical features of the 12 lakes studied is presented in table 3. Surface areas at the surveyed pool elevations range from 5.83 to 112 acres and average 34.97 acres. On the basis of the observed sizes of other final cut lakes in Illinois, we feel that the lakes selected for study are representative of such lakes in Illinois. Lake 6 was obviously among the largest observed in the initial screening from the air and lake 7 was among the smallest.

The volumes of the 12 lakes studied range from 97 to 3488 acre-feet and average 812 acre-feet. The volumes are a function of the surface area and depth. Average depths of the lakes range from 13.5 to 31.1 feet. Lakes 6 and 11 have average depths greater than 30 feet. No regional trends were noted concerning lake areas, volumes, or depths.

Table 3. Physical Features of the 12 Lakes Studied

Lake	Area (acres)	Volume (ac-ft)	Watershed area (acres)	Estimated yield potential 2-yr recurrence interval (mgd) Net surface	Groundwater	Total
1	20.14	272	233	0.16	0.29	0.45
2	11.33	225	232	0.23	0.12	0.35
3	25.57	553	80	0.07	0.23	0.30
4	18.09	472	615	0.64	0.12	0.76
5	84.60	1303	306	0.23	0.62	0.85
6	112.00	3488	2966	2.81	1.17	3.98
7	5.83	110	756	0.79	0.09	0.88
8	7.81	97	77	0.08	0.14	0.22
9	30.72	620	258	0.17	0.21	0.38
10	70.74	1659	2016	1.07	0.62	1.69
11	15.37	473	32	0.03	0.12	0.15
12	17.45	473	128	0.07	0.22	0.29
Mean	34.97	812	642	0.53	0.33	0.86

The watersheds of the 12 lakes studied are extremely variable in size and character. They range in size from 32 to 2966 acres and average 642 acres. A general description of each watershed is presented in the appendix.

The estimated yield potentials for recurrence intervals of 1.1, 2, 5, and 10 years are presented for each lake in the Lake Summaries. Two-year recurrence interval yields (or the yield that can be expected to occur once in two years) are presented in table 3. Net surface yields in million gallons per day (mgd) range from 0.03 to 2.81 and average 0.53. These estimates include runoff from the watershed minus lake evaporation. The net surface yield primarily is a function of watershed size and runoff characteristics or curve number.

The estimated groundwater yield potentials for the 12 lakes studied range from 0.09 to 1.17 million gallons per day and average 0.33 million

gallons per day. These estimates are based solely on the data collected at the Middle Grove lake site. However, as stated earlier, these estimates probably are conservative. It is very likely that lakes 4, 5, 6, 8, and 9 would be capable of yielding larger quantities of groundwater than estimated. The overburden materials for these lakes all contained significant quantities of limestone and consolidated shales that could result in a more permeable spoil and perhaps a very permeable rubble base.

The total estimated yield potential of the 12 lakes for a recurrence interval of 2 years ranges from 0.15 to 3.98 million gallons per day and averages 0.86 million gallons per day. These values are conservative estimates and are functions of the individual characteristics of each lake. These estimates also do not allow for any drawdown in lake levels (the lakes would theoretically always be full). Direct application of these values to other lakes is not recommended, and if a lake is to be used for a consumptive use, a more detailed yield analysis should be undertaken. No regional trends were noted in the yield estimates completed for the 12 lakes studied.

REGIONAL WATER NEEDS AND RESOURCES

One of the stated purposes of this project was to estimate the total potential water resource offered by final cut impoundments in Illinois. Because of the extreme variability of estimated individual lake yields and of chemical quality, to be discussed later, only very general regional estimates were made. Data assembled by Csallany and others (8) include estimates of potential water resources from groundwater, streamflow, existing man-made reservoirs, and potential reservoirs. Table 4 presents those data for the 40 counties in Illinois where surface mining of coal exists. For comparison, an estimate was made of water available from all final cut impoundments inventoried by Haynes and Klimstra (4). It should be noted that their inventory included lakes in existence through June 30, 1971.

The estimated 2000 and 2020 average water demands for each county were made by the formula developed by Roberts and others (9) and population projections of the Illinois Bureau of the Budget (10). No estimates were made for Grundy, LaSalle, Madison, Peoria, St. Clair, or Will Counties as the formula used is not applicable to industrialized areas such as these.

The total acreages of final cut impoundments for each county were multiplied by an average yield-surface area ratio (0.025 mgd/acre) obtained from the 12 lakes studied. These estimates are presented in table 4.

Assuming that the water quality from these impoundments is suitable, there appears to be significant amounts of water available from this resource in Fulton, Grundy, Knox, Perry, St. Clair, Will, and Williamson Counties. For Knox and Perry Counties, the final cut impoundments offer

Table 4. Water Demand and Supply Estimates for Surface Mined Counties

	Average water demand (mgd)		*Potential water supply (mgd)*				
	2000	*2020*	*Ground-water*	*Stream-flow*	*Existing reservoirs*	*Potential reservoirs*	*Existing final cut impoundments*
Adams	9.823	10.860	196.1	3840	0.07	58.1	0.78
Brown	0.421	0.427	19.2	4090	0.09	64.7	
Bureau	4.856	5.368	147.2	2801		60.9	6.22
Clark	1.668	2.006	56.9	550		27.4	
Crawford	2.284	2.607	32.2	550		9.0	0.02
Edgar	2.352	2.742	30.2		0.85	16.3	0.07
Fulton	6.026	7.199	50.6	3050	2.74	52.5	75.66
Gallatin	0.585	0.662	137.0	13313		27.2	0.64
Greene	1.649	1.622	67.9	4092	0.06	14.6	0.22
Grundy			32.1	2860		2.3	28.83
Hancock	2.246	2.543	93.8	3240	0.06	85.4	0.07
Henry	8.148	8.569	69.9	1280		28.4	6.37
Jackson	7.469	9.095	107.2	18004	0.37	19.9	12.08
Jefferson	5.002	6.137	14.6	1	1.19	44.4	0.27
Jersey	2.385	2.784	47.1	4090		23.5	
Johnson	1.001	1.244	20.4			38.7	0
Kankakee	14.841	16.357	95.9	383		6.4	11.02
Knox	8.662	9.742	18.7	14		21.0	24.57
LaSalle			85.9	3047		23.1	1.33
Livingston	5.239	5.587	40.8	6		3.3	
McDonough	6.527	7.667	20.3	2	0.12	15.9	0.02
Madison			94.2	17850	4.63	11.1	
Marshall	1.257	1.337	60.3	2700		7.3	0.02
Mercer	2.127	2.374	148.6	3706		66.6	0
Morgan	4.874	5.726	33.2	4090		28.8	
Peoria			58.8	2652		47.8	7.18
Perry	2.299	2.458	11.9		0.64	22.4	28.03
Pike	2.350	2.434	295.3	8530	0.79	48.8	
Pope	0.364	0.431	51.8	13310		68.2	0
Putnam	0.569	0.607	47.8	2700		27.4	
Randolph	4.242	4.788	152.9	19468	0.05	57.9	7.18
St. Clair			81.9	17908		7.8	21.79
Saline	3.099	3.452	10.7		0.18	38.8	11.31
Schuyler	0.795	0.801	31.4	4000		53.5	4.62
Scott	0.784	0.509	48.7	4090		19.7	0.02
Stark	0.473	0.441	9.9	4		27.5	2.58
Vermilion	13.513	15.732	67.6	25	5.09	29.7	12.44
Wabash	1.499	1.705	49.8	1050			0
Will			115.9	2800		16.1	19.58
Williamson	7.676	9.122	12.1	2	0.35	16.2	15.76

the largest single estimated resource. For 10 counties (Bureau, Fulton, Jackson, Knox, Perry, Randolph, Saline, Schuyler, Stark, and Williamson) the estimated yield potential from final cut impoundments exceeds the estimated 2020 water demands.

Based totally on availability, the resource potential offered by the existence of final cut impoundments is certainly worth further investigation. The fact that these water bodies already exist is of economic significance and many are located in relatively water poor areas, particularly groundwater poor areas.

WATER QUALITY

Methods and Materials

Each lake was visited on three occasions to perform field measurements and collect samples. Visits were made during November-December 1977, and February and April 1978. Because of low water temperatures, the samples collected were representative of minimal biological activity. Water samples were collected at three depths, i.e., near the surface, at mid-depth, and about two feet from the bottom. Field measurements included those for dissolved oxygen, temperature, pH, conductivity, and alkalinity. Dissolved oxygen, temperature, and conductivity determinations were made at intervals, depending on water depth, of 2 to 5 feet in the water column. Determinations for pH and alkalinity were performed on the three water samples collected at the varying water depths previously noted.

Laboratory analyses were performed on all water samples for total dissolved solids, hardness, sulfate, chloride, nitrate, fluoride, sodium, potassium, iron, and manganese. In addition, analyses were performed for certain heavy metals such as lead, cadmium, copper, zinc, mercury, boron, arsenic, selenium, silver, chromium, and barium. The analytical procedures used are listed in table 5. Analyses were performed on unfiltered samples and the results are therefore for total concentrations.

All water quality data are included in the Appendix of Lake Summaries. Except for lakes 6 and 7 there was no significant chemical stratification. Under these circumstances, reliance is placed on the concentration of mineral and heavy metal constituents observed at the mid-depth of each

Table 5. Chemical Analytical Procedures

Alkalinity	Potentiometric method in the field
pH	Glass electrode method using portable Metrohm E488 meter in the field
Hardness	EDTA tritrimetric method
Nitrate-N (NO_3-N)	Chromatrophic method
Chloride (Cl)	Argentometric method
Sulfate (SO_4)	Turbimetric method
Fluoride (F)	Fluoride electrode with Beckman 4500 meter
Sodium (Na)	Flame photometric method (atomic absorption spectrophotometer)
Potassium (K)	Flame photometric method (atomic absorption spectrophotometer)
Total dissolved solids (TDS)	Filtration and residue on evaporation at 103 to 105°C
Iron[a] (Fe)	Atomic absorption spectrophotometry
Manganese[a] (Mn)	Periodate method
Lead[a] (Pb)	Atomic absorption spectrophotometry
Cadmium[a] (Cd)	Atomic absorption spectrophotometry
Copper[a] (Cu)	Atomic absorption spectrophotometry
Zinc[a] (Zn)	Atomic absorption spectrophotometry
Mercury[a] (Hg)	Atomic absorption spectrophotometry (cold vapor)
Boron[a] (B)	Curcumin method
Arsenic[a] (As)	Atomic absorption spectrophotometry
Selenium[a] (Se)	Atomic absorption spectrophotometry
Chromium[a] (Cr)	Atomic absorption spectrophotometry
Silver[a] (Ag)	Atomic absorption spectrophotometry
Barium[a] (Ba)	Atomic absorption spectrophotometry

[a]Total concentrations

impoundment. Information regarding concentrations detected near the water surface and bottom are included in the appendix.

On one occasion, bottom sediments were obtained from each lake. Three sediment samples were obtained with an Ekman dredge from each location and composited. The composited sample was considered representative of the sediments. Portions of the composited sample were oven-dried at a low temperature (100-110°C), ground, and seived through a 64 mesh screen.

That material passing the seive was digested and analyzed for iron, lead, copper, zinc, mercury, and arsenic.

Dissolved Oxygen, Temperature, and pH

Significant stratification of dissolved oxygen concentrations and temperature occurred in only two lakes (6 and 7) during the period of sampling. Because of the rather constant temperature (9-12°C) and low dissolved oxygen maintained near the bottom of these particular impoundments, coupled with the chemical stratification occurring in them also, it is surmised that groundwater inflow governs the water quality in the lower stratum. At mid-depth the ranges observed for all lakes were:

dissolved oxygen	3.1 - 15.0 mg/l
temperature	1.2 - 12°C
pH	7.2 - 8.5

Following the disappearance of ice in April, the top 10 feet of the water column warmed to a temperature of 15 to 17°C in the impoundments located in the southern part of the state. During the same period, the lakes in the northern part ranged from 10 to 12°C. With the exception of lakes 6 and 7 the dissolved oxygen concentrations generally exceed 6 milligrams per liter (mg/l) in the water column. The values for pH are not unlike those observed in many water impoundments in Illinois.

Total Dissolved Solids, Hardness, Sulfate, Alkalinity

Total dissolved solids at mid-depth ranged from 349 to 2870 milligrams per liter. Table 6 lists the average concentrations at mid-depth for each of the 12 impoundments. A distribution of the concentrations observed for total dissolved solids is depicted in figure 2. Close examination of the

Table 6. Average Chemical Concentrations at Mid-Depth

(In milligrams per liter)

	Lake number					
	1	*2*	*3*	*4*	*5*	*6*
Total dissolved solids	1795	709	409	676	2502	2774
Alkalinity*	223	232	124	97	104	234
Hardness*	1263	519	342	406	1233	1187
Sulfate	1135	356	164	331	1705	1834
Chloride	3	7	3	15	42	28
Nitrate-N	0.35	0.80	0.16	1.05	0.09	0.25
Fluoride	0.20	0.23	0.30	0.31	0.31	0.57
Sodium	41	39	12	44	239	364
Potassium	6	4	2	4	5	9
Iron	0.17	0.06	0.17	0.43	0.10	0.16
Manganese	0.26	0.09	0.05	0.18	0.10	0.90
	7	*8*	*9*	*10*	*11*	*12*
Total dissolved solids	775	1996	1576	944	444	1564
Alkalinity*	207	184	132	182	118	76
Hardness*	486	1335	684	697	359	1057
Sulfate	334	1376	972	563	217	1074
Chloride	31	5	34	18	3	7
Nitrate-N	0.64	0.17	0.15	0.36	0.18	0.37
Fluoride	0.32	0.40	0.42	0.20	0.21	0.43
Sodium	59	78	190	28	11	56
Potassium	5	5	3	5	3	7
Iron	0.11	0.21	0.12	0.19	0.10	0.39
Manganese	1.16	0.53	0.07	0.06	0.02	0.13

[a]as $CaCO_3$

plotted data indicates two basic populations. Lakes 2, 3, 4, 7, 10, and 11 generally contain total dissolved solids less than 1000 milligrams per liter; the other six lakes contain total dissolved solids in excess of 1000 milligrams per liter.

Hardness concentrations were also excessive with values ranging from 258 to 1445 milligrams per liter as calcium carbonate ($CaCO_3$). Average concentrations at mid-depths are shown in table 6, and distribution of the data for hardness is shown in figure 2. Here it seems the line of best fit

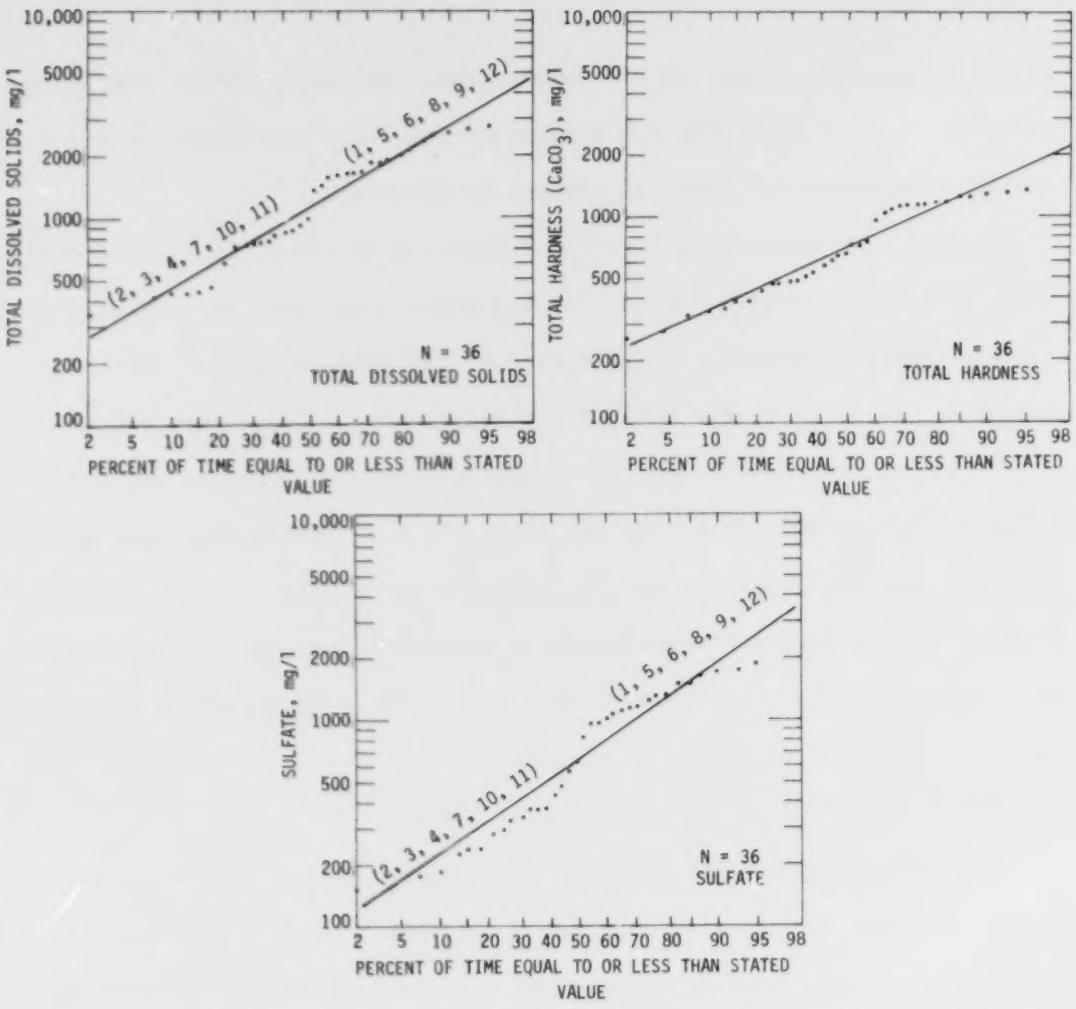
TOTAL DISSOLVED SOLIDS, mg/l
10,000
5000
2000
1000
500
200
100
(2, 3, 4, 7, 10, 11)
(1, 5, 6, 8, 9, 12)
N = 36
TOTAL DISSOLVED SOLIDS
2 5 10 20 30 40 50 60 70 80 90 95 98
PERCENT OF TIME EQUAL TO OR LESS THAN STATED VALUE
TOTAL HARDNESS ($CaCO_3$), mg/l
N = 36
TOTAL HARDNESS
PERCENT OF TIME EQUAL TO OR LESS THAN STATED VALUE
SULFATE, mg/l
(2, 3, 4, 7, 10, 11)
(1, 5, 6, 8, 9, 12)
N = 36
SULFATE
PERCENT OF TIME EQUAL TO OR LESS THAN STATED VALUE

Figure 2. Probability distributions for total dissolved solids, total hardness, and sulfate at mid-depths.

is fairly representative for all impoundments and that hardness concentrations equal to or less than 700 milligrams per liter are likely to occur in final cut impoundments about 50 percent of the time.

Sulfate concentrations were often high ranging from 153 to 1984 milligrams per liter. Average values for mid-depth conditions are included in table 6, and a probability distribution of the sulfate data is shown in figure 2. Here, as in the case of total dissolved solids, the data seem to consist of two populations. The population of lower concentration has a limit of about 600 milligrams per liter and the lakes within that population are identical to those for the lower range of total dissolved solids. Because of this apparent relationship a regression analysis was performed for total dissolved solids and sulfate (figure 3). The equation developed is:

Total dissolved solids = 224 + 1.34 sulfate

To further explore the chemical constituents responsible for total dissolved solids a step-wise regression was performed incorporating, in addition to sulfate concentrations, the observed concentrations of total hardness. The equation developed is:

Total dissolved solids = 198 + 0.086 hardness + 1.287 sulfate

From statistical coefficients the constituents of hardness (calcium and magnesium) together with sulfate account for 98 percent of the variation in total dissolved solids concentrations.

The alkalinity of the impoundment waters consist mainly of bicarbonates (HCO_3). The concentrations range from 69 to 255 milligrams per liter as $CaCO_3$. Average concentrations at mid-depth are included in table 6.

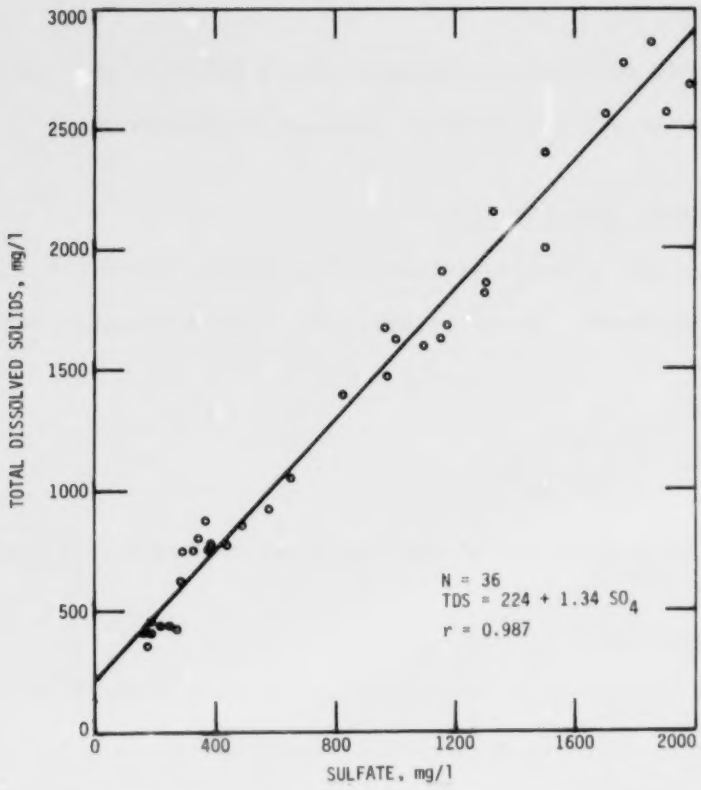

Figure 3. Relationship of total dissolved solids and sulfates at mid-depths of 12 impoundments.

As in the case of total dissolved solids, sulfates, and hardness, the impoundments cannot be classified on a geographical basis for alkalinity either. However, they can be grouped according to concentration, as follows:

Alkalinity < 150 mg/l - Lakes 2, 4, 5, 9, 11, 12
Alkalinity > 150 mg/l - Lakes 1, 3, 6, 7, 8, 10

Step-wise regression techniques were used to determine relationships between hardness (Ca^{++} and Mg^{++}) and alkalinity (HCO_3^-) and sulfate ($SO_4^=$). The following equation was developed.

Hardness = 192 + 0.69 alkalinity + 0.59 sulfate

Statistical coefficients suggest that alkalinity and sulfate account for 92 percent of the variation in hardness concentrations.

Chloride, Nitrate, and Fluoride

The variation in concentrations of chloride, nitrate-N, and fluoride in the 12 impoundments is not significant. The following ranges were observed:

Chloride	2-4 mg/l
Nitrate-N	0.02-1.2 mg/l
Fluoride	0.17-0.64 mg/l

Average concentrations at mid-depth are included in table 6.

Sodium and Potassium

Sodium concentrations varied widely, ranging from 10 to 400 milligrams per liter. Potassium concentrations were more limited ranging from 2 to 11 milligrams per liter. Average concentrations at the mid-depth of each lake are included in table 6. A distribution of the sodium data is shown in figure 4. Here the data suggest that the impoundments, without regard to geographical location, fall in three categories based on sodium content. The grouping and ranges are:

10-13 mg/l -- Lakes 2, 11
25-80 mg/l -- Lakes 1, 3, 4, 7, 8, 10, 12
160-400 mg/l-- Lakes 5, 6, 9

Iron and Manganese

Iron and manganese concentrations ranged from 0.01 to 0.96 and 0.01 to 1.58 milligrams per liter, respectively, at mid-depth. Average values are shown in table 6. Near bottom samples reflected very high concentrations of these substances in lakes 6 and 7. For lake 6, iron concentrations

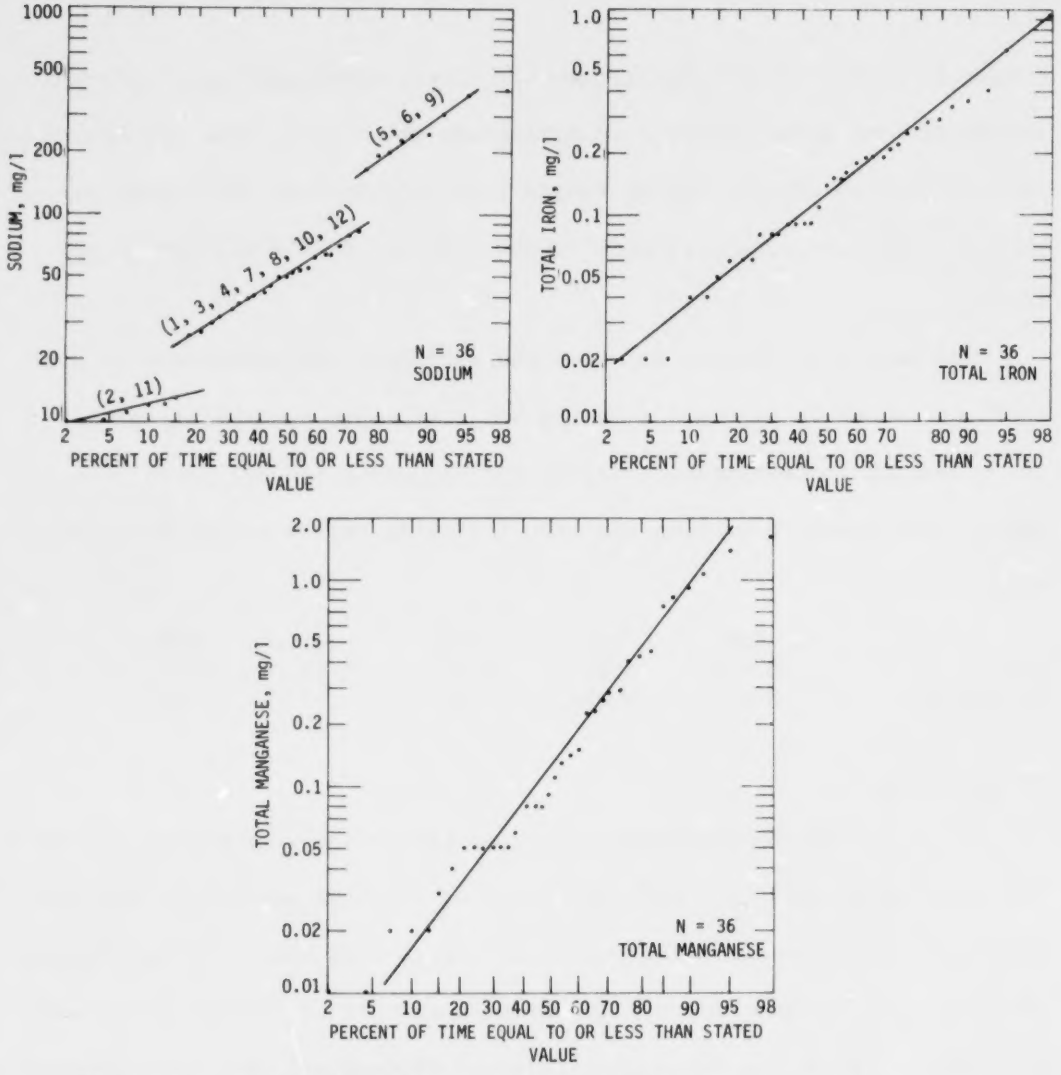

Figure 4. Probability distributions for sodium, total iron, and total manganese at mid-depths.

ranged from 20.2 to 24.3 milligrams per liter; corresponding manganese concentrations were 5.9 and 4.65 milligrams per liter. Near the bottom of lake 7 the iron concentrations ranged from 0.20 to 2.02 milligrams per liter, whereas manganese concentrations ranged from 5.4 to 9.2 milligrams per liter.

The data distribution for iron and manganese concentrations at mid-depth are shown in figure 4. On the basis of these probability plots, the mid-depth concentrations of iron and manganese (in mg/l) are anticipated to be equal to or less than the following values at the designated frequencies:

	10%	25%	50%	75%	90%
Iron	0.038	0.07	0.13	0.25	0.45
Manganese	0.017	0.034	0.13	0.37	0.95

Heavy Metals

The range of concentrations observed for 11 heavy metals at mid-depth are included in table 7. Concentrations of chromium and silver were not detected. Selenium concentrations were always less than 0.001 milligrams per liter and barium concentrations were always less than 0.1 milligrams per liter. Except for the higher range of cadmium and lead concentrations, the heavy metal content of the impoundment waters was not unlike that found in other Illinois surface waters.

Sediments

The concentrations of iron, lead, copper, zinc, cadmium, mercury, and arsenic found in composited samples of sediment from the final cut impoundments are summarized in table 8. Whether or not these values are typical

of water basins developed in strip mining areas is not known. However, there are sufficient data at hand to compare the concentrations of these trace elements, except cadmium, with those observed in other Illinois impoundments.

Table 7. Range of Heavy Metal Concentrations at Mid-Depths

	mg/l
Cadmium	0.00-0.04
Copper	0.01-0.08
Zinc	0.02-0.10
Boron	0.10-0.50
Lead	0.00-0.17
Arsenic	<0.001-0.005
Selenium	<0.001
Chromium	ND
Silver	ND
Barium	<0.1
Mercury	0.04-0.88[a]

[a] µg/l

Table 8. Heavy Metals in Sediments[a]

(In parts per million)

Lake	*Iron*	*Lead*	*Copper*	*Zinc*	*Cadmium*	*Arsenic*
1	27,710	46	48	89	3	0.50
2	17,430	27	27	48	0	0.33
3	23,760	28	27	48	2	0.40
4	25,120	28	15	54	1	0.46
5	18,530	28	14	55	0	0.33
6	23,760	34	18	74	2	0.46
7	19,430	41	30	78	3	0.46
8	23,111	46	18	68	5	0.45
9	24,030	28	23	54	1	0.41
10	25,820	68	40	820	18	0.68
11	32,680	35	34	82	3	0.21
12	29,400	46	44	70	4	0.56

[a] Composite of 3 samples

Recent studies of Rend Lake, Cedar Lake, and Alto Pass Reservoir -- all serving as public water supplies -- and Little Cedar Lake have yielded information on heavy metals in sediments. The following ranges of concentrations (in parts per million) are offered for comparison.

	Lead	Copper	Zinc
Cedar Lake	15-26	10-19	35-54
Rend Lake	19-30	15-30	44-79
Alto Pass Reservoir	35-60	16-34	42-77
Little Cedar Lake	45	30	89-95
Final Cut Impoundment	27-68*	14-48	48-89

	Iron	Arsenic	Mercury
Cedar Lake	10,000-21,000		.01-.03
Rend Lake	13,000-28,000		.05
Alto Pass Reservoir	14,000-23,000		.02-.03
Little Cedar Lake	26,500		.03-.05
Final Cut Impoundment	17,500-32,100	0.2-0.7	

* excludes a value of 820 ppm

A review of the comparative data suggests that concentrations of lead, copper, zinc, and iron observed in the sediments of final cut impoundments are very similar to those observed in other water impoundments in Illinois. The soils of strip mines in Illinois are reported to vary from 27 to 30 parts per million for lead; 33 to 37 parts per million for copper, and 90 to 125 parts per million for zinc. These values are not unlike those found in the sediments of the final cut impoundments.

The importance of the cadmium concentrations observed is not clear. At this time comparative data have not been obtained.

Summary

- With the exception of two lakes, stratification of temperature, dissolved oxygen, and chemical content did not occur during the period of sampling. Dissolved oxygen content generally exceeded 6

milligrams per liter and pH values were not unlike other Illinois surface waters.

- Concentrations of total dissolved solids, hardness, and sulfates are excessive.
- The variation in total dissolved solids content is principally a function of hardness and sulfate concentrations.
- Most of the hardness is in non-carbonate form.
- Although the lakes can be grouped according to ranges of value for certain water quality characteristics such as total dissolved solids, sulfate, alkalinity, and sodium, they cannot be classified in terms of water quality on the basis of geographical location.
- Concentrations of chloride, nitrate, fluoride, sodium, and potassium were not found in excessive quantities.
- Manganese concentrations generally exceeded those found in the surface waters of Illinois.
- Iron content, except in the bottom water stratum, was not excessive.
- With the exception of lead and cadmium levels, the heavy metal content was not significantly different from other Illinois surface waters.
- If significant dissolved oxygen stratification occurs during the warm months, it is likely that anoxic conditions will be created in the lower water strata resulting in the production of hydrogen sulfide and the introduction of certain heavy metals into the water column.

CHEMICAL SUITABILITY

The water quality of the final cut impoundments has been evaluated to determine the suitability of each location as a source for *potable water*, *irrigation*, and *livestock watering*. Reliance has been placed on the regulations in Illinois for evaluating use of the waters as public water supplies (11). The recommendations developed by a committee of the National Academy of Sciences and the National Academy of Engineering (12) were used for assessing the fitness of the impounded waters for irrigation and livestock watering. The water quality requirements for each use, for those elements examined during the study, are included in the tables for each use. The average values derived at mid-depth for each impoundment are used to ascertain the suitability of their waters for the uses previously noted.

Public Water Supply

The water quality requirements in table 9 for a public water supply source are predicated on the assumption that the source of water being considered will be usable with no more than routine forms of water treatment, i.e., coagulation, sedimentation, sand filtration, and disinfection. The limitations established for each constituent are based on several considerations. These include adverse physiological effects on humans, taste preferences, aesthetic considerations, user preference, and toxicity to humans.

Where physiological and toxic effects on humans are the principal motives for establishing a limitation in concentration for a particular

element, there is no latitude for ignoring the limitation. However, in cases where taste, aesthetics, and user preference are the prime reasons for a limitation, some judgment can be applied in permitting use of the water, despite concentrations in excess of the limitation. Such judgment could be applied for elements such as chloride, sulfate, total dissolved solids, iron, and manganese. Nevertheless, for the purposes of this report, the waters of each impoundment were deemed *satisfactory* or *unsatisfactory* solely on the basis of existing standards and recommendations. The findings are given in table 9.

Only two impoundments maintain water quality satisfactory as a source of potable water. These are lakes 3 and 11. All of the other 10 locations contain water exceeding the limits on total dissolved solids, sulfate, and manganese; eight exceed standards for lead; seven exceed standards for cadmium; and two exceed standards for iron.

Irrigation

The water quality considerations for irrigation are not well defined. The effects are directly related to soil characteristics, age and type of plants, frequency of application, and crop tolerance. For evaluation purposes guidelines for salinity and trace element tolerances were relied upon and are shown in table 10.

In the case of salinity a concentration of 2000 milligrams per liter total dissolved solids was considered the upper limit. Concentrations between 500 to 2000 milligrams per liter may have a detrimental effect upon sensitive crops, but with careful management a limit of 2000 milligrams per

Table 9. Chemical Suitability of Each Lake as a Source for Public Water Supply

Criteria		*Lake number*											
	(mg/l)	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*
Total dissolved solids	500	U	U	S	U	U	U	U	U	U	U	S	U
Sulfate	250	U	U	S	U	U	U	U	U	U	U	S	U
Chloride	250	S	S	S	S	S	S	S	S	S	S	S	S
Nitrate-N	10	S	S	S	S	S	S	S	S	S	S	S	S
Fluoride	1.4	S	S	S	S	S	S	S	S	S	S	S	S
Iron	0.30	S	S	S	U	S	S	S	S	S	S	S	U
Manganese	0.05	U	U	S	U	U	U	U	U	U	U	S	U
Lead	0.05	U	U	S	S	U	U	S	U	U	U	S	U
Cadmium	0.01	U	S	S	U	U	S	S	U	U	U	S	U
Selenium	0.01	S	S	S	S	S	S	S	S	S	S	S	S
Barium	1.00	S	S	S	S	S	S	S	S	S	S	S	S
Arsenic	0.01	S	S	S	S	S	S	S	S	S	S	S	S
Mercury	0.002	S	S	S	S	S	S	S	S	S	S	S	S
Chromium	0.05	S	S	S	S	S	S	S	S	S	S	S	S
Silver	0.05	S	S	S	S	S	S	S	S	S	S	S	S

Note: S means satisfactory; U means unsatisfactory

Table 10. Chemical Suitability of Each Lake as a Source for Irrigation Water Supply

Criteria		*Lake number*											
	(mg/l)	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*
Total dissolved solids	2000	S	S	S	S	U	U	S	S	S	S	S	S
Fluoride	1.0	S	S	S	S	S	S	S	S	S	S	S	S
pH	4.5-9.0	S	S	S	S	S	S	S	S	S	S	S	S
Iron	5.0	S	S	S	S	S	S	S	S	S	S	S	S
Manganese	0.2	U	S	S	S	S	U	U	U	S	S	S	S
Lead	5.0	S	S	S	S	S	S	S	S	S	S	S	S
Cadmium	0.01	U	S	S	U	U	S	S	U	U	U	S	U
Copper	0.20	S	S	S	S	S	S	S	S	S	S	S	S
Zinc	2.0	S	S	S	S	S	S	S	S	S	S	S	S
Boron	0.75	S	S	S	S	S	S	S	S	S	S	S	S
Selenium	0.02	S	S	S	S	S	S	S	S	S	S	S	S
Arsenic	0.1	S	S	S	S	S	S	S	S	S	S	S	S
Chromium	0.1	S	S	S	S	S	S	S	S	S	S	S	S

Note: S means satisfactory; U means unsatisfactory

liter seems reasonable. The limits on trace elements are predicated on waters being applied continuously on all soils. The findings are given in table 10. There are also limits of 0.2 and 5 milligrams per liter for nickel and aluminum, respectively, but these were not assessed in this study.

Only three lakes contain water suitable for irrigation. They are locations 2, 3, and 11. The remaining nine impoundments are considered unsuitable mainly because of excess concentrations of total dissolved solids, manganese, or cadmium.

Livestock Watering

The animals considered as livestock include beef and dairy cattle, sheep, swine, horses, and poultry. As in the case of other water uses, the concentrations of the elements which may render a water unsuitable for use by livestock are quite variable (table 11). These are affected by age, sex, species, and the physiological condition of the animals; water intake; diet and its composition; the chemical form of the element; and the temperature of the environment. Therefore the development of recommendations for safe concentrations of substances in water is difficult. The criteria used have an appropriate margin of safety and are considered reasonable for most conditions. Levels of 5 and 0.1 milligrams per liter for aluminum and vanadium, respectively, also were not assessed in this study.

The evaluation of the 12 impounded waters for livestock water sources is summarized in table 11. All impoundments contain water satisfactory for livestock watering based upon the analyses performed.

Table 11. Chemical Suitability of Each Lake as a Source for Livestock Watering

Criteria		*Lake number*											
	(mg/l)	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*
Total dissolved solids	3000	S	S	S	S	S	S	S	S	S	S	S	S
Nitrate-N	100	S	S	S	S	S	S	S	S	S	S	S	S
Fluoride	2	S	S	S	S	S	S	S	S	S	S	S	S
pH	7.0-9.2	S	S	S	S	S	S	S	S	S	S	S	S
Lead	0.1	S	S	S	S	S	S	S	S	S	S	S	S
Cadmium	0.05	S	S	S	S	S	S	S	S	S	S	S	S
Copper	0.50	S	S	S	S	S	S	S	S	S	S	S	S
Zinc	25	S	S	S	S	S	S	S	S	S	S	S	S
Boron	5.0	S	S	S	S	S	S	S	S	S	S	S	S
Mercury	0.01	S	S	S	S	S	S	S	S	S	S	S	S
Selenium	0.05	S	S	S	S	S	S	S	S	S	S	S	S
Arsenic	0.20	S	S	S	S	S	S	S	S	S	S	S	S
Chromium	1.0	S	S	S	S	S	S	S	S	S	S	S	S

Note: S means satisfactory; U means unsatisfactory

Summary

- The average concentrations of constituents determined at mid-depth of the lakes were considered representative of water quality.
- Only 2 lakes (3 and 11) are considered satisfactory as sources of public water supplies.
- The waters of 10 impoundments exceed water supply standards for total dissolved solids, sulfate, and manganese; 8 exceed lead standards; and 7 exceed standards for cadmium.
- Only 3 lakes (2, 3, and 11) contain water suitable for irrigation. Excess concentrations of cadmium are present in 7 impoundments.
- All impoundments are suitable sources for livestock watering.

RECOMMENDATIONS

Potential Use Recommendations

The estimated yield potential of final cut impoundments in Illinois is significant. On a regional or county basis, it has been shown that these lakes can produce large quantities of water. At the local level, the potential use of these resources appears even more appealing.

On the basis of the chemical quality of the lakes studied and published water quality standards, the potential uses do not look as promising. Only 2 lakes are considered satisfactory for public water supply use, 3 for irrigation use, and all 12 are satisfactory for livestock watering. However, before dismissing the use of these lakes based solely on published water quality standards, the water quality of the impoundments should be compared with the water quality of alternative sources of water.

As an example, the village of Astoria in the southern tip of Fulton County began using a final cut impoundment as a source of public water supply in late 1976. This move was part of a continuing effort by the town to find a chemically acceptable and reliable water supply.

The first public water supply for Astoria was obtained from a 1660-foot deep well drilled in 1897. Use of this water was limited because of its poor quality.

In 1924 the well was abandoned and water was obtained from an earthen dam reservoir constructed northeast of the town. Water from the reservoir was of good quality (see table 12) but the capacity of the lake was insufficient. In the early 1950s a pipeline was constructed to carry water

Table 12. Chemical Analysis of the Village of Astoria Water Sources (In milligrams per liter)

	1660-ft deep well 6/1/20	*70-ft deep well 6/28/70*	*Old city reservoir 12/3/75*	*Final cut lake 3/15/77*
Sample No.	ISWS 43156	EPA 00288	EPA A9830	EPA B37488
Iron (Fe)	0.36	5.8	0.5	0.3
Manganese (Mn)	0.00	0.4	0.10	0.23
Silica (SiO_2)	12.50	5.0		4.8
Calcium (Ca)	145.00	110	27	86
Magnesium (Mg)	65.10	50	19	57
Ammonia (NH_4)	3.09	9	0.06	0.08
Sodium (Na)	1062[a]	22.5	4.3	34
Nitrate (NO_3)	2.66	0.0	4.0	2.6
Chloride (Cl)	1125.00	1.0	8	7.3
Sulfate (SO_4)	1087.00	0.0	10	260
Alkalinity	240	560	150	250
Hardness		490	147	502
Residue	3671.0	648	210	687

[a]Sodium and potassium

to the reservoir from a private lake south of town. This additional source of supply continued to be used mainly during the summer months until 1976. By 1976, the pipeline from the private lake had badly deteriorated and the village negotiated a contract with Amax Coal Company to use a final cut impoundment first as a supplement to their lake supply and then as the sole source of water for the village.

Water quality data for the village deep well, reservoir, and final cut impoundment are given in table 12 along with data for a shallow well in the area. The quality of water from the final impoundment is comparable to that from the shallow well but more highly mineralized than water from the old reservoir. However, the 630-acre-foot volume of the final cut impoundment provides an adequate and more dependable supply than the 86-acre-foot

(original capacity) reservoir.

Because of the relatively abundant groundwater resources in northeastern Illinois and the active development of final cut impoundments for private recreational uses in the region, we suggest that the recreational uses continue to have priority. In western and southern Illinois, the use of final cut impoundments for consumptive water uses should be investigated at the local level on an individual basis. Regional planning commissions, consulting engineers, and village officials should be made aware of the potential final cut impoundment resources in their areas and encouraged to investigate the economics and suitability of their use.

Recommendations for Further Study

On the basis of the results of this project and general knowledge of strip mine related problems, the following suggestions for further study are made:

1. One or more final cut impoundments and watersheds should be properly instrumented and data gathered for a two or three year period to more accurately determine runoff-infiltration relationships and the response of groundwater to recharge events.
2. More detailed analysis of the groundwater regimes of spoil materials is needed. A series of wells and observation wells for pumping tests and analysis in spoil materials of varying geologic parentage is needed.
3. If final cut impoundments are to be considered a water resource, the sedimentation rates experienced by these lakes need to be determined. Estimates of soil losses from strip mine lands also

are needed to assess the effects of these lands on regional water quality parameters.

4. To more accurately characterize the quality of final cut impoundment waters, samples need to be collected for a minimum period of one year.
5. On the basis of the apparent differences in quality of runoff waters and groundwater in some final cut impoundments, an assessment of the effects of pumping a lake on water quality should be undertaken.
6. Regional assessment of water needs and resources should be examined in more detail. This probably should be accomplished at the local or county level.

APPENDIX. LAKE SUMMARIES

1 -- Middle Grove Lake

Middle Grove lake is located in Section 19, T9N, R4E, Knox County. The lake and surrounding property are owned by Peabody Coal Company who opened the mine in 1950 and closed it in 1952. The Springfield (No. 5) coal was mined with a 40 cubic yard Marion shovel. The coal was overlain by 50 to 75 feet of overburden materials of which 20 to 30 feet was predominately clay. The rock overburden was a black shale with isolated fossiliferous dark limestone concretions (13).

The general shape of the lake and location of range lines where depth measurements were taken are shown in figure 5. The area and volume of the lake at elevation 649 feet above mean sea level are 20.14 acres and 272 acre-feet, respectively. Stage-volume and stage-area curves for the lake are presented in figure 6. The maximum measured and calculated average depths are 30 and 13.5 feet, respectively. Representative cross sections illustrating the general lake profile are shown in figure 7. Cross sections R3-R4, R11-R12, and R21-R22 are for the final cut portion of the lake and R23-R24 is for the incline or haul road portion.

The watershed of this lake is limited to within ½ mile of the lake and covers approximately 233 acres. The entire watershed consists of reclaimed spoil material that is relatively flat and planted in alfalfa.

The pumping test conducted on Middle Grove lake provided the data on which all other groundwater contribution estimates are based. A propane powered Ford V-8 engine driving a Berkley pump (Model No. B4EYPMBHCW) was used during the test. The pump was set up at the east end of the lake and the pump discharge pipe extended about 250 feet south over the crest of an emergency spillway cut into the spoil materials. To monitor the pumping rate, a Parshall flume was constructed in the downstream portion of the emergency spillway. The channel between the pump discharge pipe and flume was lined with 6 mil polyethylene to insure that all water pumped passed through the flume. During the pumping test, the Parshall flume was cali-

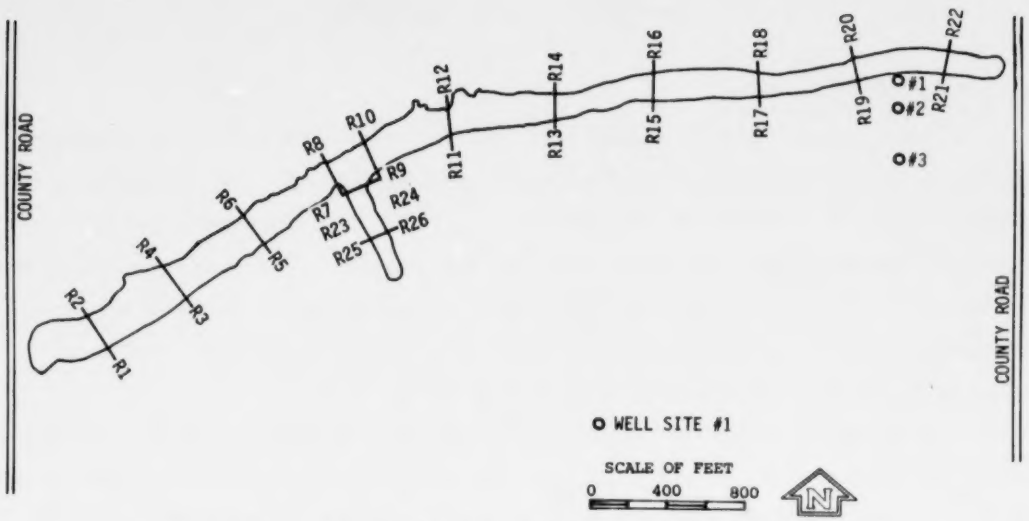

Figure 5. Middle Grove lake range line locations.

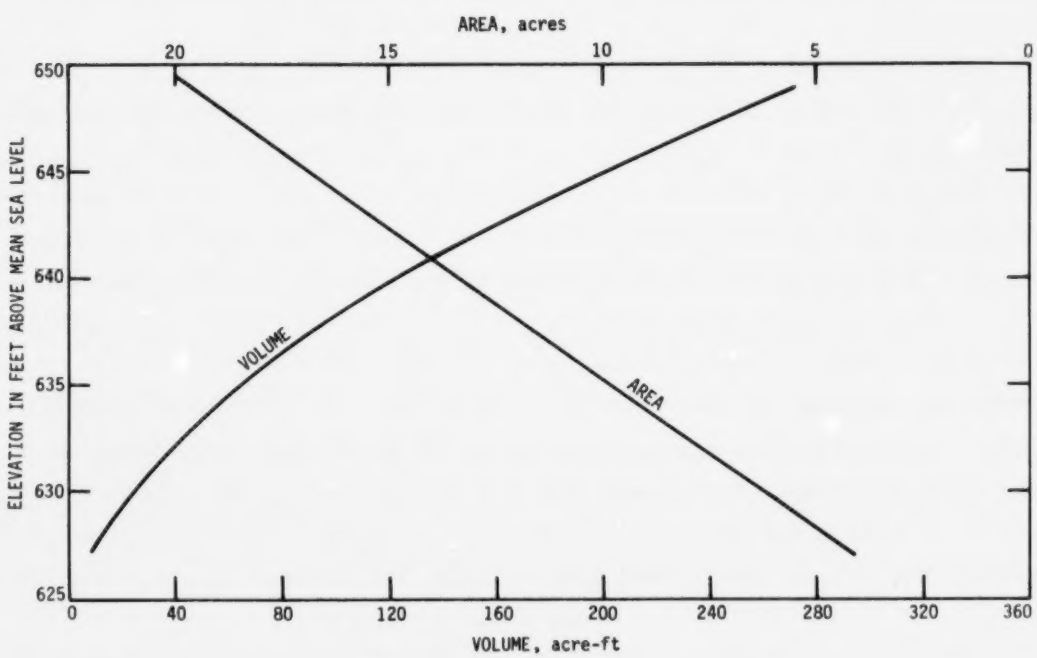

Figure 6. Stage-volume, stage-area curves for Middle Grove lake.

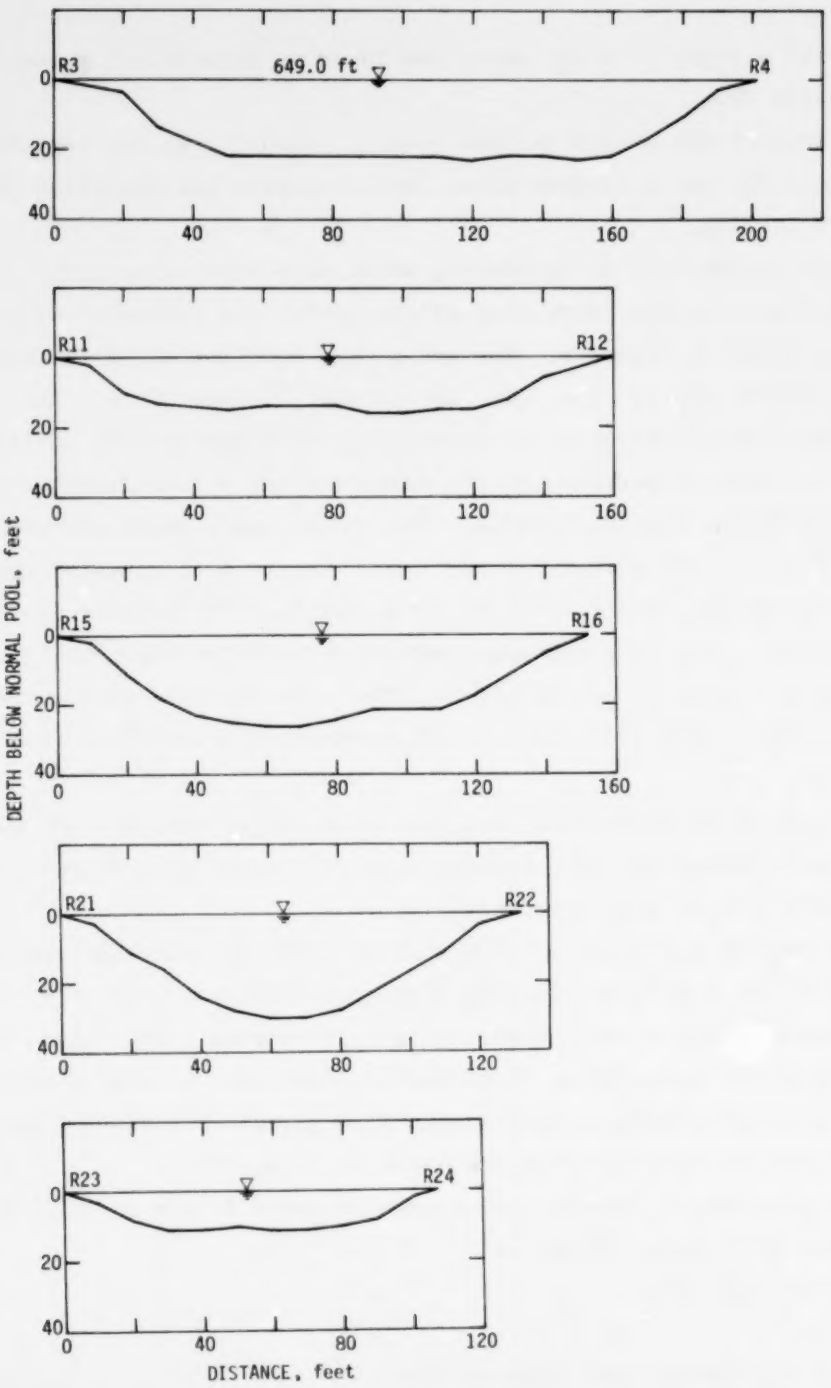

Figure 7. Representative cross sections of Middle Grove lake.

brated with a Pigmy velocity meter and found to be within 1 percent of the design rated flow.

To monitor the change in lake levels, a staff gage was installed for direct readings and a Stevens water level recorder was installed for continuous recording.

Three piezometers or monitoring wells also were constructed in the spoil materials on the south side of the lake. The locations of these wells are shown on figure 5. The wells were constructed of 1½ inch diameter PVC pipe to depths of 47, 48, and 48 feet, respectively. The bottom 10 feet of each well casing was slotted with a hack saw and the anular spaces between the slotted portions of the wells and the 7-inch diameter bore holes were filled with pea gravel. The anular space above the gravel in each well was filled with drill cuttings. Figure 8 illustrates the vertical and horizontal location of the wells relative to the lake profile. Water levels in the lake and spoil materials prior to the pumping test also are shown in figure 8. It should be noted that the lake is located in a regional groundwater flow system with movement of groundwater toward the south.

To provide precipitation data for water budget analysis and watershed curve number determinations, a wedge type rain gage and a Belfort weighing type recording rain gage were installed.

The pumping test started on April 24, 1978, at 9:30 a.m. and ended on May 1, 1978, at 1:30 p.m. Pumping stopped 5 different times for repairs and maintenance for a total down time of 810 minutes. The total amount of water pumped was measured at 10,619,900 gallons over a total period of 9226 minutes [average pumping rate of about 1150 gallons per minute (gpm)]. Selected pumping test data are presented in table 13.

The groundwater contribution column of table 14 was calculated by the simplified water budget equation

$$GW = Q - \Delta V_r + E_r$$

where:

GW = groundwater contribution (gpm)

Q = average pumping rate at time t (gpm)

ΔV_r = average rate of change in lake volume at time t (gpm)

E_r = rate of lake evaporation (gpm)

The rate of lake evaporation during the pumping test was estimated at 0.15 inches per day or 57 gpm for the 20.14-acre lake. With the same evaporation rate for a 63-hour period immediately following the pumping test and recorded recovery data, a groundwater contribution rate of about 200 gpm was calculated. For the purpose of estimating the groundwater yield potential of this lake, the more conservative 200 gpm rate determined from the recovery data was selected. To apply this value to other lakes, 200 gpm ÷ 5500 feet (the length of the lake) or 0.036 gpm/ft was used.

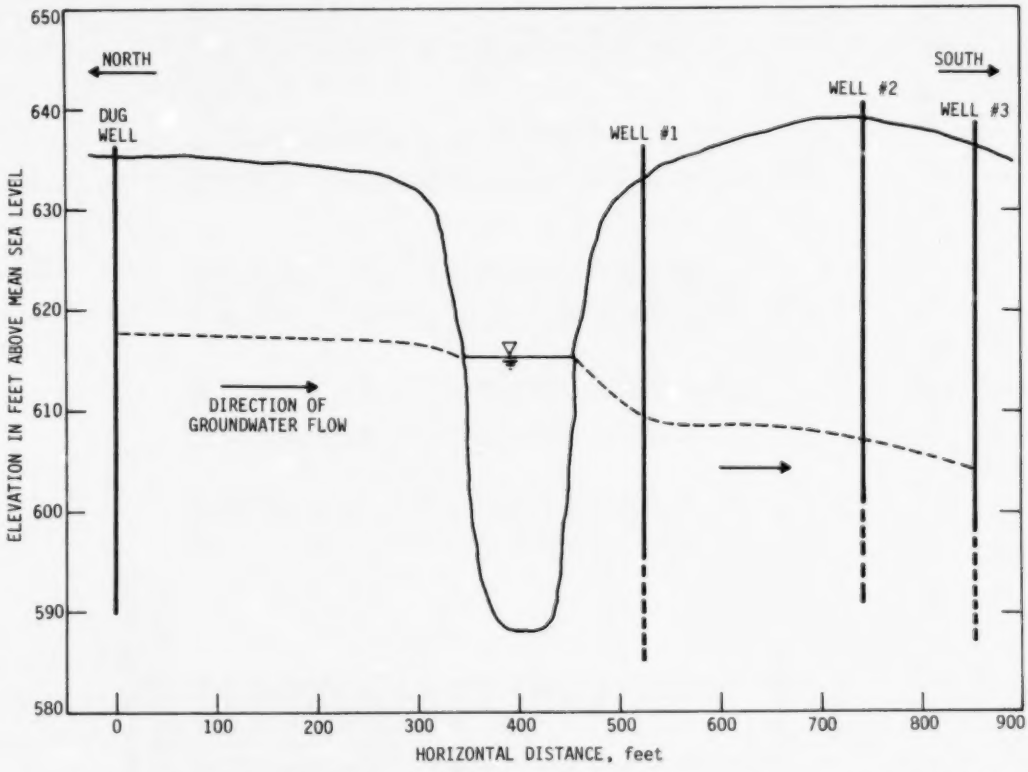

Figure 8. Profile of Middle Grove lake and surrounding spoil materials.

Table 13. Selected Pumping Test Data, Middle Grove Lake

Date	Time	Elapsed time (minutes)	Lake level[a]	Well #1[b]	Well #2[b]	Well #3[b]	Total pumpage (gallons)	Total change in lake volume (gallons)	Groundwater contribution (gpm)
4/24	9:30 A		4.38	24.37	32.08	31.52			
	10:00 A	30	4.37	24.38	32.10	31.54	38,379	65,620	
	11:00 A	90	4.36	24.37	32.08	31.54	115,110	131,240	
	12:00 P	150	4.36	24.38	32.10	31.54	191,850	131,240	461
	2:00 P	270	4.34	24.38	32.11	31.55	345,330	262,480	364
	4:00 P	390	4.33	24.39	32.13	31.58	498,810	328,110	495
	6:00 P	510	4.29	24.42	32.14	31.57	649,290	590,600	172
	8:00 P	630	4.28	24.44	32.14	31.58	799,770	656,220	285
	10:00 P	750	4.27	24.45	32.15	31.55	953,250	721,840	365
4/25	12:00 A	870	4.25	24.48	32.16	31.56	1,106,730	853,080	349
	4:00 A	1120	4.22	24.50	32.16	31.54	1,413,690	1,049,950	382
	10:00 A	1480	4.17	24.61	32.20	31.52	1,682,280	1,378,060	263
	8:00	2080	4.12	24.69	32.21	31.49	2,296,200	1,706,170	340
4/26	8:00 A	2800	4.00	24.81	32.25	31.48	3,217,080	2,493,632	315
	8:00 P	3520	3.90	24.94	32.29	31.45	4,131,960	3,149,852	336
4/27	8:00 A	4240	3.87	25.01	32.36	31.47	4,451,730	3,346,720	318
	4:00 P	4720	3.80	25.11	32.39	31.50	5,002,100	3,609,200	352
	8:45 P	5005	3.77	25.17	32.42	31.52	5,321,860	3,806,070	359
4/28	12:00 P	5920	3.62	25.33	32.51	31.58	6,474,150	4,987,270	308
5/1	1:30 P	9226	3.18	26.00	32.97	31.85	10,619,870	7,874,630	355

[a]Staff gage reading, feet
[b]Feet below measuring point

A watershed curve number (CN) value for this lake was determined with data from 2 storm events that occurred the week following the pumping test. During the first event 0.92 inches of precipitation fell during a 31-hour period resulting in a 0.11 foot rise in lake level. During the second event 2.13 inches of precipitation fell during a 38-hour period resulting in a 0.35 foot rise in lake level.

Total runoff amounts for each storm were calculated with the water budget equation

$$R = \Delta V - PA_l - GW + E_l$$

where:

R = runoff

ΔV = change in lake

P = precipitation

A_l = area of the lake

GW = groundwater contribution

E_l = evaporation from the lake

These runoff values were set equal to the SCS equation for determining runoff and CN values of 64 and 65 were determined, respectively. Since these values were determined from single rainfall events and monthly rainfall totals are being used for runoff analysis, a CN value of 60 was selected for this lake. Precipitation data from Canton were used to simulate the 20 years of runoff.

On the basis of the calculated net runoff values and a groundwater contribution capability of 0.036 gpm/ft x 5500 ft or 200 gpm, the estimate yields presented in table 14 were determined.

Chemical analysis data for water samples collected December 1977 and February and April 1978 are presented in table 15.

Table 14. Estimated Yield Potential of Middle Grove Lake

	Yield (mgd) for given recurrence interval (yr)			
	1.1	*2*	*5*	*10*
Net surface yield	0.06	0.16	0.22	0.25
Groundwater contribution	0.29	0.29	0.29	0.29
Total	0.35	0.45	0.51	0.54

Table 15. Chemical Analysis Data, Middle Grove Lake

Depth	Temp	DO	Field pH	Field alk	Conductivity at 25°C	TDS	Hard	Cl	F	SO_4	NO_3-N
December 1977, 4 to 6 inch ice											
0	1.0	15.0	8.1	220		2004	1287	6	0.19	1115	0.23
5	2.0	15.0									
10	2.0	14.9									
15	2.2	14.9	8.0	217		1888	1313	0	0.17	1148	0.21
20	3.0	14.4									
25	3.5	11.3									
30	3.8	10.6	8.0	217		1876	1273	0	0.20	1156	0.18
February 1978, 12 inch ice											
0	0.1	9.3	7.4	235	2700	1851	1320	3	0.25	1241	0.25
5	2.1	9.4			2720						
10	3.0	9.4			2656						
15	3.8	8.1	7.4	237	2754	1868	1300	5	0.24	1254	0.24
20	4.0	6.7			2754						
25	4.2	6.2			2752						
30	4.5	6.2	7.25	263	2752	1895	1294	4	0.25	1271	0.27
April 1978											
0	12.0	10.0	8.1	216	2070	1647	1175	6	0.2	985	0.51
5	12.0	10.0			2070						
10	12.0	10.0			2070						
15	12.0	10.0	8.1	216	2070	1630	1175	5	0.2	1004	0.60
20	12.0	10.0			2070						
25	12.0	9.9			2070						
30	6.0	6.1	7.6	228	2219	1772	1265	7	0.2	1075	0.55

	December 1977			February 1978			April 1978		
	Surface	Middle	Bottom	Surface	Middle	Bottom	Surface	Middle	Bottom
Fe	0.31	0.26	0.24	0.11	0.06	0.17	0.20	0.19	0.23
Mn	0.08	0.05	0.57	0.32	0.29	0.63	0.45	0.45	0.54
Pb	0.08	0.07	0.08	0.17	0.17	0.17	ND	ND	ND
Cd	0.03	0.03	0.04	0.02	0.02	0.02	ND	ND	ND
Hg	0.49	0.48	0.40	0.38	0.81	0.46	0.11	0.08	0.08
K	5.8	5.5	5.5	4.5	4.5	4.6	6.0	5.8	6.2
Na	46	42	42	35	35	30	46	45	49
Cu	0.02	0.02	0.02	0.01	0.02	0.02	ND	0.02	0.02
Zn	0.06	0.05	0.06	0.05	0.06	0.06	0.01	0.03	0.05
As	<0.001	<0.001	<0.001	<0.002	<0.002	<0.002	<0.001	<0.001	<0.001
Se	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Ag	ND	ND	ND	ND	ND	ND	0.01	ND	ND
Cr	ND	ND	ND	ND	ND	ND	ND	ND	ND
Ba	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
B	0.4	0.4	0.5	0.4	0.4	0.4	0.3	0.3	0.3

Note: Temperature, °Celsius; conductivity, μ mhos; Hg, μg/l; all other values except pH, mg/l

2 -- Sunspot West Lake

Sunspot West is located in Section 9 and 10, T3N, R1E, Fulton County. The lake and surrounding property is owned by Amax Coal Company who opened the mine in 1963 and closed it in 1965. The Colchester (No. 2) coal was mined with a 5761 Marion shovel. The coal was overlain by 50 to 75 feet of overburden materials of which 30 to 40 feet was clay and till. The rock overburden was a gray sandy shale (13).

The general shape of the lake and locations of range lines where depth measurements were taken are shown in figure 9. The area and volume of the lake at elevation 583 feet above mean sea level are 11.33 acres and 225 acre-feet, respectively. Stage-volume and stage-area curves for the lake are presented in figure 10. The maximum measured and calculated average depths are 33 and 19.9 feet, respectively. Representative cross sections illustrating the lake profile are shown in figure 11.

The watershed of this lake extends approximately 1 mile to the west and covers about 232 acres. About 30 percent of the watershed consists of spoil material while the remainder is cultivated farm land. Because of the high percentage of farm land a curve number (CN) value of 70 was selected for runoff calculations. Precipitation data from Canton were used for the 20 years of simulated runoff.

On the basis of the calculated net runoff values and a groundwater contribution of 0.036 gpm/ft x 2400 feet (the approximate length of the lake), the estimated yields presented in table 16 were determined.

Chemical analysis data for water samples collected December 1977 and February and April 1978 are presented in table 17.

Table 16. Estimated Yield Potential of Sunspot West Lake

	Yield (mgd) for given recurrence interval (yr)			
	1.1	*2*	*5*	*10*
Net surface yield	0.12	0.23	0.30	0.33
Groundwater contribution	0.12	0.12	0.12	0.12
Total	0.24	0.35	0.42	0.45

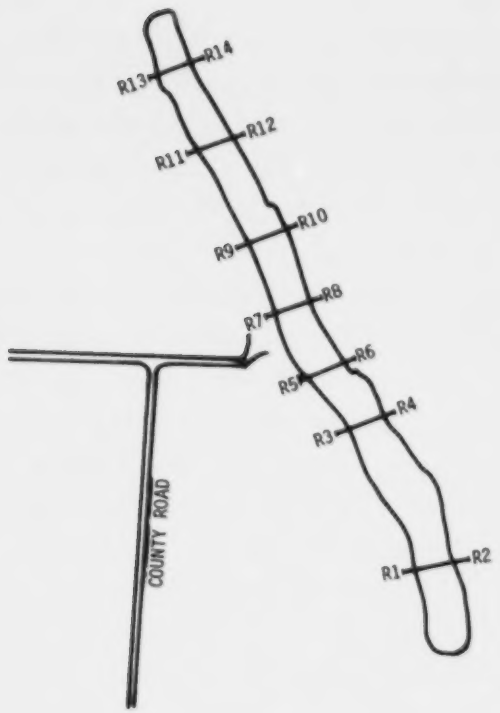

Figure 9. Sunspot West lake range line locations.

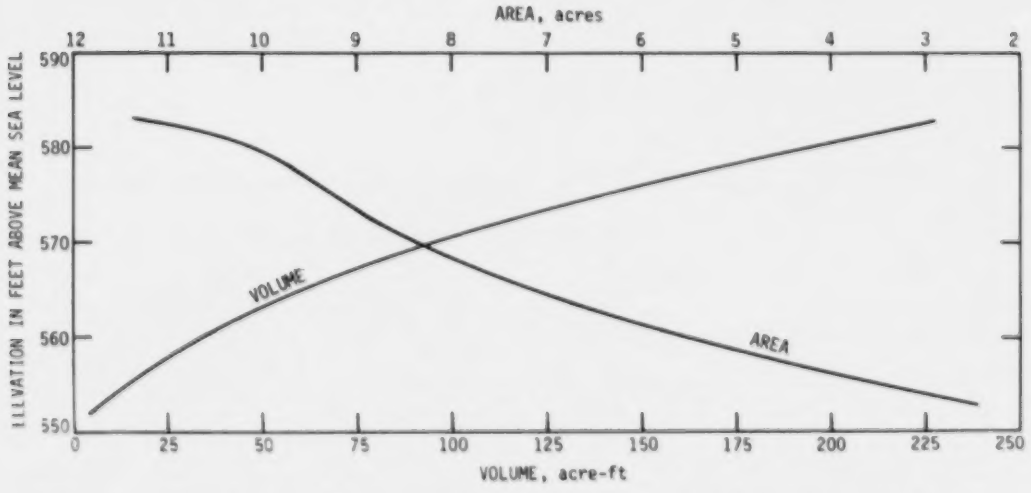

Figure 10. Stage-volume, stage-area curves for Sunspot West lake.

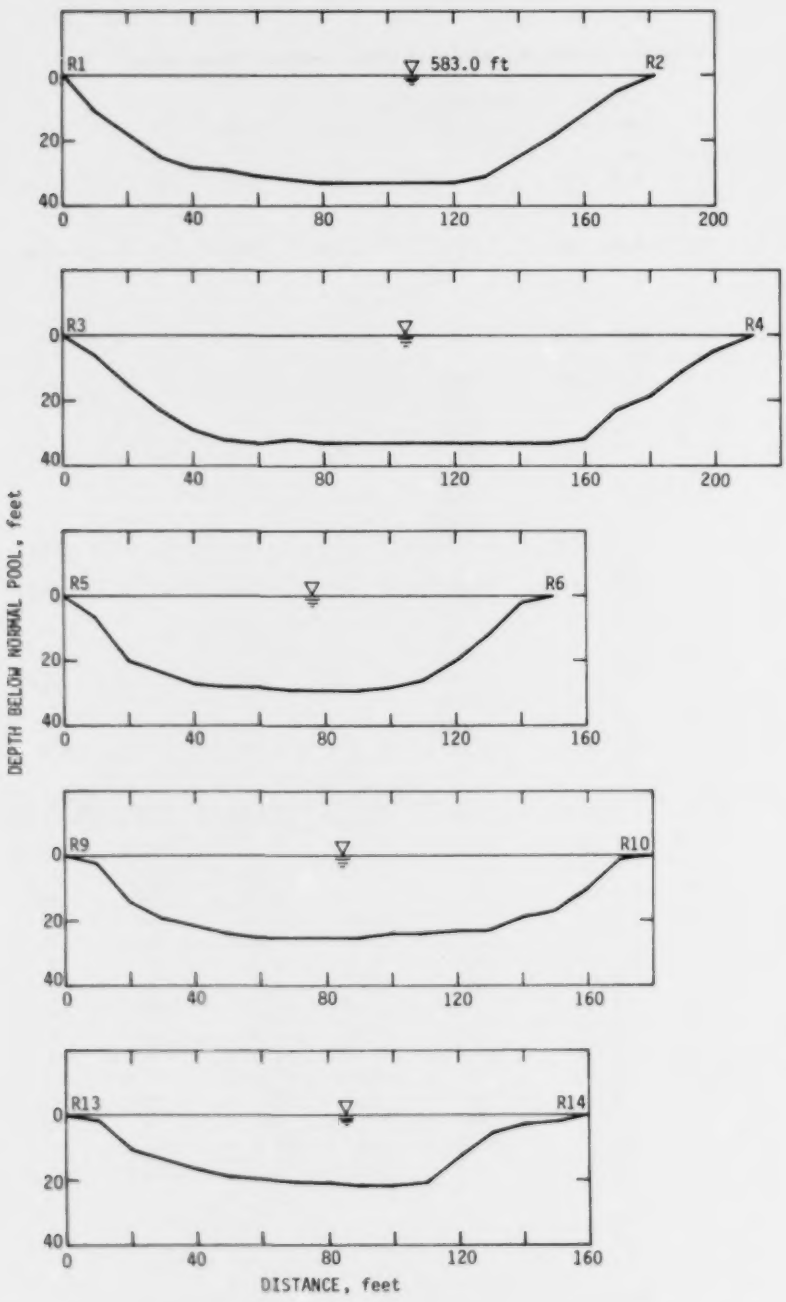

Figure 11. Representative cross sections of Sunspot West lake.

Table 17. Chemical Analysis Data, Sunspot West Lake

Depth	Temp	DO	Field pH	Field alk	Conductivity at 25°C	TDS	Hard	Cl	F	SO_4	NO_3-N
December 1977, 5 inch ice											
0	1.0	13.8	8.4	227		726	507	8	0.22	326	0.72
5	1.0	13.6									
10	1.5	13.4									
15	1.5	13.2	8.4	230		728	540	8	0.23	340	0.71
20	1.5	12.5									
25	2.0	11.6									
30	3.0	6.8									
32	4.0	5.0	7.7	253		801	607	8	0.23	374	0.44
February 1978, 8 inch ice											
0	1.0	11.2	7.8	283	1400	644	516	5	0.26	270	1.92
5	3.0	11.2			1494						
10	3.0	11.2			1527						
15	3.2	11.2	7.8	250	1577	786	580	6	0.27	443	0.79
20	4.0	7.6			1620						
25	4.2	6.3			1620						
30	4.5	6.1			1792						
33	5.0	4.2	7.1	323	2120	957	716	8	0.26	538	0.55
April 1978											
0	11.0	15.8	8.3	198	1013	603	438	9	0.2	281	0.93
5	11.0	15+			1013						
10	10.5	14.4			1061						
15	10.2	13.8			1076						
20	10.2	13.2	7.9	193	1104	613	438	8	0.2	286	0.89
25	10.0	12.5			1104						
30	10.0	11.4			1104						
35	9.0	6.2	7.6	202	1349	646	454	9	0.2	297	0.93

	December 1977			February 1978			April 1978		
	Surface	Middle	Bottom	Surface	Middle	Bottom	Surface	Middle	Bottom
Fe	0.07	0.09	0.09	0.05	0.02	0.13	0.07	0.08	0.14
Mn	0.21	0.13	0.50	0.15	0.11	0.88	0.03	0.03	0.06
Pb	0.05	0.05	0.05	0.14	0.14	0.14	ND	ND	ND
Cd	0.03	0.03	0.03	0.02	0.02	0.02	ND	ND	ND
Hg	0.46	0.38	0.45	0.82	0.41	0.49	0.17	0.23	0.49
K	4.3	4.3	4.4	2.7	3.7	4.0	4.1	4.2	4.3
Na	38	39	44	25	40	45	36	37	38
Cu	<0.01	0.08	0.04	<0.01	0.01	0.02	ND	0.02	0.02
Zn	0.02	0.12	0.11	0.01	0.04	0.06	ND	0.05	0.06
As	0.001	0.001	0.001	<0.002	<0.002	<0.002	0.001	<0.001	<0.001
Se	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Ag	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cr	ND	ND	ND	ND	ND	ND	ND	ND	ND
Ba	<0.1	<0.1	<0.1	<0.01	<0.1	<0.1	<0.1	<0.1	<0.1
B	0.4	0.4	0.4	0.3	0.4	0.5	0.3	0.3	0.3

Note: Temperature, °Celsius; conductivity, μ mhos; Hg, μg/l; all other values except pH, mg/l

3 -- Sunspot East Lake

Sunspot East lake is located in Section 6, T3N, R2E, Fulton County. The lake and surrounding property is owned by Amax Coal Company who opened the mine in 1969 and closed it in 1971. The Colchester (No. 2) coal was mined with a 5761 Marion shovel. The coal was overlain by 50 to 75 feet of overburden materials of which 30 to 40 feet are clay, till, and sandy clay. The rock overburden was a soft gray sandy shale (13).

The general shape of the lake and location of range lines where depth measurements were taken are shown in figure 12. The area and volume of the lake at elevation 585 feet above mean sea level are 25.57 acres and 553 acre-feet, respectively. Stage-volume and stage-area curves for the lake are presented in figure 13. The maximum measured and calculated average depths are 38 and 21.6 feet, respectively. Representative cross sections illustrating the lake profile are shown in figure 14.

The watershed of this lake is limited to the immediate lake area and covers about 80 acres. All of the watershed is reclaimed spoil planted in clover and grass. The relatively steep slopes encountered in this watershed as compared with those at Middle Grove resulted in selecting a curve number (CN) of 65 for this watershed. Precipitation data from Canton were used to simulate runoff for the 20 years of interest.

On the basis of the calculated net runoff values and a groundwater contribution of 0.036 gpm/ft x 4400 ft (the approximate length of the lake), the estimated yields presented in table 18 were determined.

Chemical analysis data for water samples collected December 1977 and February and April 1978 are presented in table 19.

Table 18. Estimated Yield Potential of Sunspot East Lake

	Yield (mgd) for given recurrence interval (yr)			
	1.1	*2*	*5*	*10*
Net surface yield	0.02	0.07	0.10	0.12
Groundwater contribution	0.23	0.23	0.23	0.23
Total	0.25	0.30	0.33	0.35

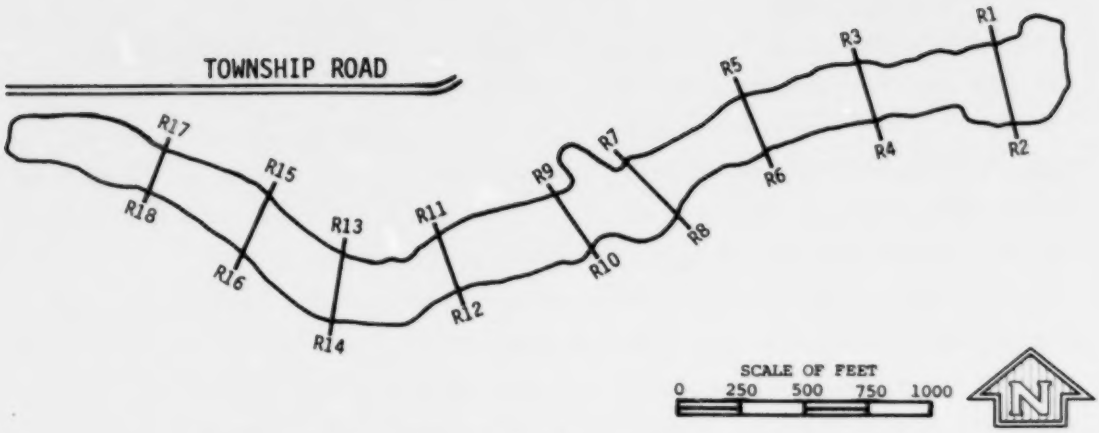

Figure 12. Sunspot East lake range line locations.

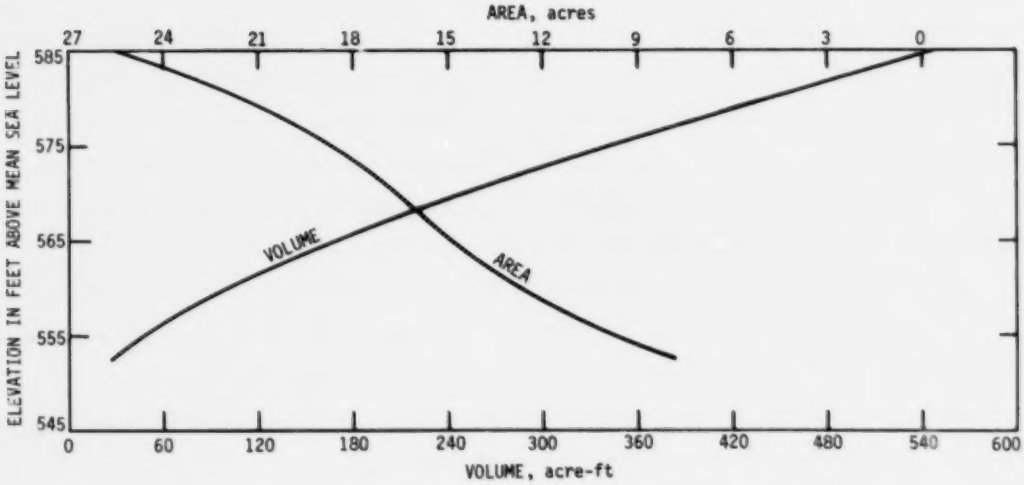

Figure 13. Stage-volume, stage-area curves for Sunspot East lake.

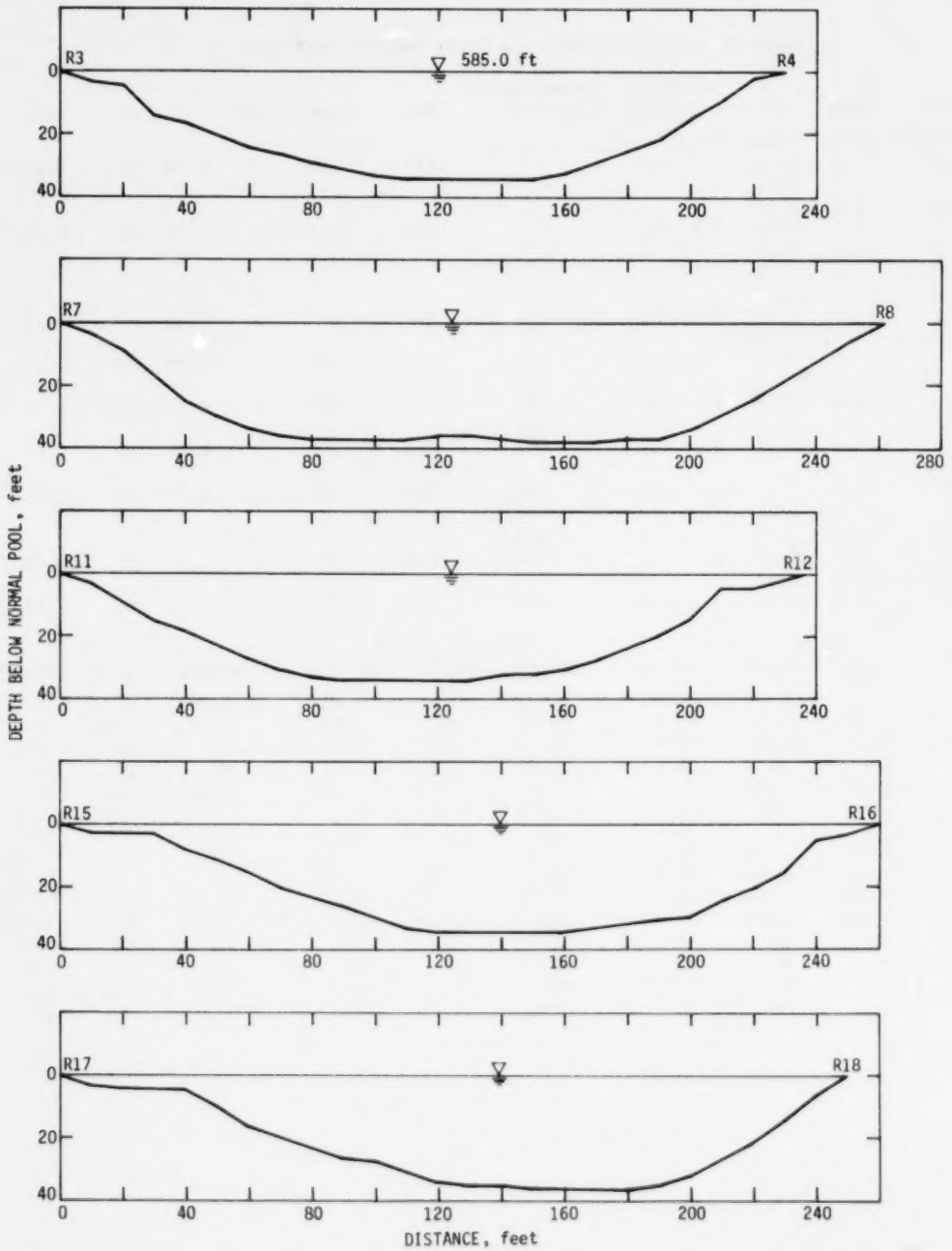

Figure 14. Representative cross sections of Sunspot East lake.

Table 19. Chemical Analysis Data, Sunspot East Lake

Depth	Temp	DO	Field pH	Field alk	Conductivity at 25°C	TDS	Hard	Cl	F	SO_4	NO_3-N
December 1977, 3 inch ice											
0	1.1	12.4	8.5	129		417	520	2	0.28	180	0.05
5	1.1	12.2									
10	1.2	12.0									
15	1.2	12.0	8.4	126		416	387	2	0.28	162	0.11
20	1.2	11.9									
25	1.5	11.8									
30	1.8	11.8									
32	1.8	11.3	8.4	126		395	347	2	0.30	162	0.10
February 1978, 10 inch ice											
0	1.0	14.0	8.4	131	578	417	380	2	0.33	162	0.05
5	3.0	13.5			598						
10	3.0	13.2	8.3	129	606	412	360	2	0.33	153	0.18
15	3.5	13.2			599						
20	3.8	13.0	8.0	129	599	409	340	2	0.33	144	0.16
April 1978											
0	11.2	12.5	8.5	110	580	348	280	4	0.3	178	0.24
5	11.2	12.6			580						
10	11.2	12.6			580						
15	11.0	12.2	8.5	110	580	349	280	4	0.3	177	0.18
20	10.5	12.0			578						
25	10.0	11.5	8.4	110	580	353	282	5	0.3	178	0.29

	December 1977			February 1978			April 1978		
	Surface	Middle	Bottom	Surface	Middle	Bottom	Surface	Middle	Bottom
Fe	0.12	0.15	0.16	0.01	<0.01	0.21	0.09	0.14	0.44
Mn	0.09	0.05	0.09	0.05	0.03	0.08	0.01	0.01	0.03
Pb	<0.02	<0.02	<0.02	0.10	0.08	0.10	ND	ND	ND
Cd	ND	ND	ND	0.01	0.01	0.02	ND	ND	ND
Hg	0.44	0.68	0.46	0.26	0.51	0.59	0.38	0.20	0.20
K	1.9	1.9	1.9	1.8	1.8	1.8	1.9	1.9	1.9
Na	11	10	10	14	12	12	13	13	13
Cu	<0.01	0.03	0.03	<0.01	0.02	0.01	ND	0.01	0.01
Zn	0.02	0.06	0.04	<0.01	0.04	0.05	ND	0.03	0.01
As	<0.001	0.001	0.001	<0.002	<0.002	<0.002	<0.001	<0.001	0.001
Se	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Ag	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cr	ND	ND	ND	ND	ND	ND	ND	ND	ND
Ba	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
B	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	ND

Note: Temperature, °Celsius; conductivity, μ mhos; Hg, μg/l; all other values except pH, mg/l

4 -- Pinckneyville No. 2 Lake

Pinckneyville No. 2 is located in Section 17, T5S, R2W, Perry County. The lake and surrounding property is owned by Consolidated Coal Company who opened the mine in February 1976 and closed it in August 1977. The Herrin (No. 6) coal was mined with a 1350 Ransome Rapier Dragline (33 cubic yards). The spoil materials were placed in the same relative positions vertically as before mining, that is, unconsolidated materials laying atop the consolidated materials. The coal was overlain by 60 to 75 feet of overburden of which about 20 feet was glacial materials. The rock overburden consisted of black shaley slate overlain by gray limestone with dark shaley streaks (14).

The general shape of the lake and locations of range lines where depth measurements were taken are shown in figure 15. The area and volume of the lake at elevation 411 feet above mean sea level are 18.09 acres and 472 acre-feet, respectively. Stage-volume and stage-area curves for the lake are presented in figure 16. The maximum measured and calculated average depths are 60 and 26.1 feet, respectively. Representative cross sections illustrating the general lake profile are shown in figure 17.

The watershed of this lake extends approximately 1½ miles to the east and covers about 615 acres. About 10 percent of the watershed is mined land and the remainder is cultivated farm land. Because of the high percentage of farm land in the watershed a curve number (CN) of 70 was selected for simulated runoff calculations. Precipitation data from DuQuoin were used for the 20 years of interest.

On the basis of the calculated net runoff values and a groundwater contribution of 0.036 gpm/ft x 2300 ft (the length of the lake), the yields presented in table 20 were determined.

Total 20. Estimated Yield Potential of Pinckneyville No. 2 Lake

	Yield (mgd) for given recurrence interval (yr)			
	1.1	*2*	*5*	*10*
Net surface yield	0.38	0.64	0.80	0.89
Groundwater contribution	0.12	0.12	0.12	0.12
Total	0.50	0.76	0.92	1.01

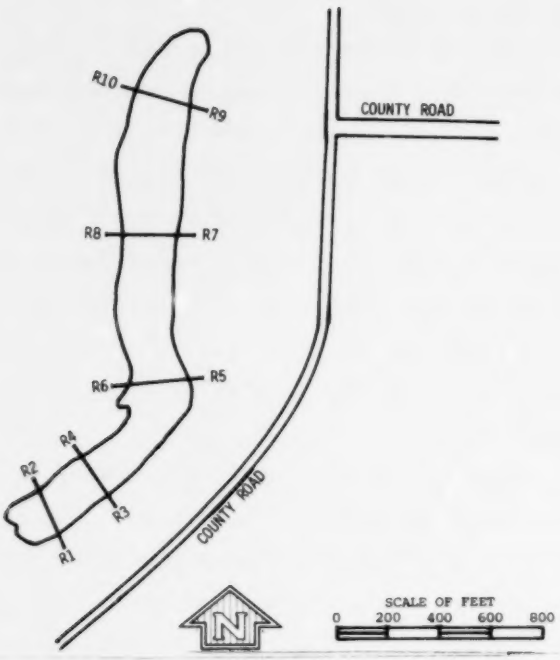

Figure 15. Pinckneyville No. 2 lake and range line locations.

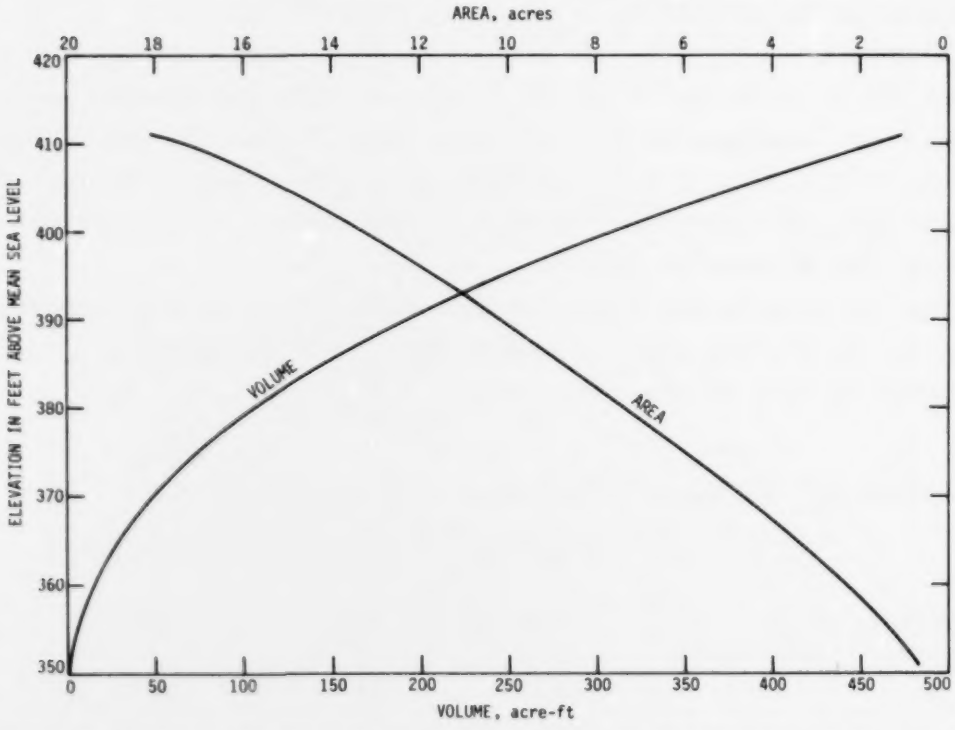

Figure 16. Stage-volume, stage-area curves for Pinckneyville No. 2 lake.

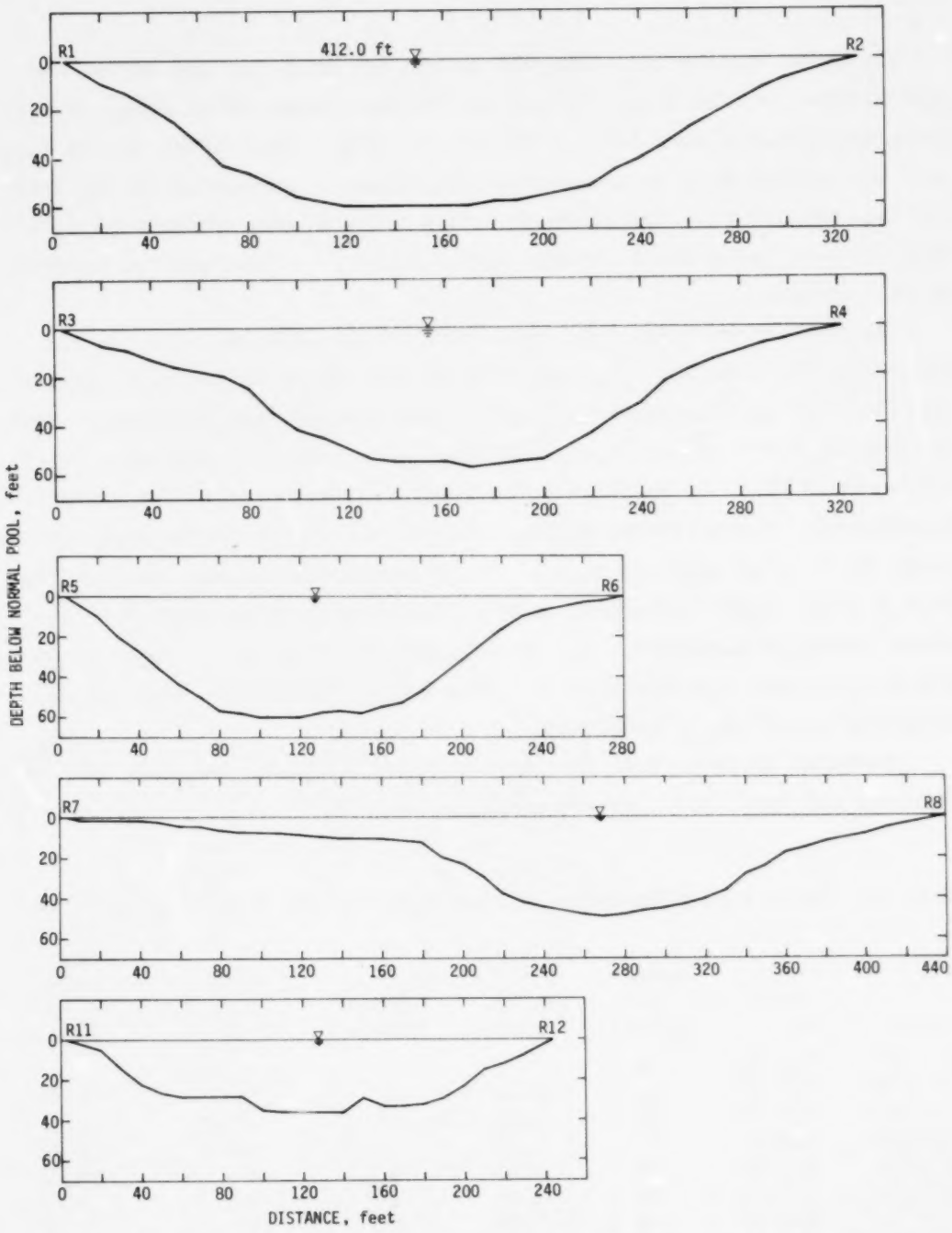

Figure 17. Representative cross sections of Pinckneyville No. 2 lake.

As noted earlier this lake was chosen for study because mining had just stopped and the final cut pit was in the process of filling. Water level measurements were made at regular intervals and a water budget analysis was attempted to delineate the groundwater contribution to the lake. For this analysis precipitation data from DuQuoin, pan evaporation data from Carlyle, and a CN of 70 were used. Table 21 summarizes the results of this effort.

Because of the relatively small size of the mine operation in the immediate lake area and the short life of the mining activity, a relatively small area of spoil material around the pit probably was dewatered. When the pit was first observed, another lake just across the haul road at the north end of the lake had a water level 52 feet higher than the water level in this pit. A significant seepage zone near the base of the road fill between the 2 lakes also was noted. It is likely that seepage through the road fill and rapid recharging of the spoil materials accounts for the almost constant groundwater inflow into the lake. However, these rates probably are not representative of groundwater yields that would be experienced under pumped conditions.

Chemical analysis data for water samples collected December 1977 and February and April 1978 are presented in table 22.

Table 21. Water Budget Analysis of Pinckneyville No. 2 Lake and Watershed

Date	*Lake level (MSL)*	*Lake volume (ac-ft)*	*Precip. (inches)*	*Runoff (inches)*	*Lake evap. (inches)*	*Groundwater contrib. (gpm/ft)*
10/11/77	356.58	9				
10/24/77	357.60	11	0.24	0	1.15	0.02
11/11/77	359.80	15	1.90	0.1	0.68	-0.01
11/21/77	362.45	22	1.66	0.1	0.23	0.02
11/30/77	364.00	26	0.91	0	0	0.04
12/13/77	377.79	90	3.44	1.0	0	0.08
1/4/78	384.33	140	0.59	0	0	0.22
1/23/78	384.88	145	0.95	0	0	0.02
2/6/78	384.79	144	0.19	0	0	-0.01
3/15/78	405.01	377				

Table 22. Chemical Analysis Data, Pinckneyville No. 2 Lake

Depth	Temp	DO	Field pH	Field alk	Conductivity at 25°C	TDS	Hard	Cl	F	SO_4	NO_3 -N
December 1977, ice cover											
0	2.0	11.9	7.8	103		864	433	12	0.29	342	0.95
2	2.0	11.9									
4	2.0	11.9									
6	2.0	11.9									
8	2.0	11.8									
10	2.0	11.8									
12	2.0	11.5	7.8	108		870	487	13	0.42	373	1.02
14	2.0	11.5									
16	2.5	11.4									
18	2.5	11.1									
20	2.5	11.0									
22	3.0	9.8	7.8	121		984	513	15	0.33	433	1.00
February 1978, 9 inch ice											
0	1.0	16.3	8.7	101	1050	739	472	21	0.35	391	0.72
2	3.0	16.4			1079						
4	3.8	13.5			1102						
6	4.0	12.8			1134						
8	4.0	12.4			1134						
10	4.0	12.3			1134						
12	4.0	12.3			1134						
14	4.0	12.3			1134						
16	4.0	12.2	7.7	106	1134	756	472	22	0.31	378	0.94
20	4.0	12.0			1134						
25	4.0	12.0			1166						
30	5.0	7.5	7.7	106	1303	770	472	21	0.29	378	1.14
April 1978											
0	17.0	10.2	8.7	78	732	424	258	12	0.2	243	1.06
5	17.0	10.2			732						
10	15.8	10.0			738						
15	9.6	10.1			763						
20	8.5	10.2			785						
25	8.0	10.3			796						
30	7.0	10.5	7.6	78	775	432	258	11	0.2	243	1.22
35	6.9	10.5			775						
40	6.7	10.4			785						
45	6.5	10.4			785						
55	6.5	10.4			800						
60	6.8	9.3	7.6	78	901	434	274	12	0.2	243	1.36

	December 1977			February 1978			April 1978		
	Surface	Middle	Bottom	Surface	Middle	Bottom	Surface	Middle	Bottom
Fe	0.85	0.65	0.75	0.30	0.36	0.98	0.1	0.28	1.03
Mn	0.38	0.23	0.25	0.27	0.27	0.25	0.04	0.05	0.11
Pb	0.08	0.05	0.05	0.11	0.11	0.13	ND	ND	ND
Cd	0.03	0.03	0.03	0.01	0.02	0.02	ND	ND	ND
Hg	0.32	0.38	0.44	0.56	0.54	0.40	0.07	0.04	0.11
K	4.5	4.5	4.3	3.9	3.9	4.1	3.8	3.7	3.8
Na	50	51	58	50	50	50	33	32	33
Cu	0.03	0.02	0.01	<0.01	0.02	0.01	0.01	0.01	0.01
Zn	0.06	0.04	0.03	0.01	0.06	0.04	ND	0.02	0.02
As	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.001	<0.001	<0.001
Se	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Ag	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cr	ND	ND	ND	ND	ND	ND	ND	ND	ND
Ba	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
B	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1

Note: Temperature, °Celsius; conductivity, μ mhos; Hg, μg/l; all other values except pH, mg/l

5 -- Old DuQuoin Pit

Old DuQuoin Pit is located in Section 6, T5S, R2W, Perry County. It is owned by Consolidated Coal Company who opened the mine in mid-1950 and closed it in July 1974. The Herrin (No. 6) coal was mined with a 5761 Marion shovel (65 cubic yards) and a 1060 Bucyrus Erie bucket wheel excavator (9 buckets at 2.75 cubic yards each). The spoil materials were placed in the same vertical positions as before mining, that is, unconsolidated materials on top of consolidated materials. The overburden materials range in depth from 30 to 90 feet with 20 to 65 feet of unconsolidated clays, tills, and sand. The rock overburden consisted of dark gray shale and limestone layers (14).

The general shape of the lake and locations of range lines where depth measurements were made are shown in figure 18. The area and volume of the lake at elevation 439 feet above mean sea level are 84.6 acres and 1303 acre-feet, respectively. Stage-volume and stage-area curves for the lake are presented in figure 19. The maximum measured and calculated average depths are 55 and 15.4 feet, respectively. Representative cross sections illustrating the general lake profile are shown in figure 20.

The watershed of this lake covers approximately 306 acres all of which is strip mine land planted in clover and grass. A curve number (CN) value of 60 was used for runoff calculations. Precipitation data from DuQuoin were used for the 20 years of simulated runoff calculations.

On the basis of the calculated net runoff values and a groundwater contribution of 0.036 gpm/ft x 10,390 feet (the combined total lengths of the various lake parts), the estimated yields presented in table 23 were determined.

Chemical analysis data for water samples collected November 1977 and February and April 1978 are presented in table 24.

Table 23. Estimated Yield Potential of Old DuQuoin Pit Lake

	Yield (mgd) for given recurrence interval (yr)			
	1.1	*2*	*5*	*10*
Net surface yield	0.05	0.23	0.34	0.40
Groundwater contribution	0.62	0.62	0.62	0.62
Total	0.67	0.85	0.96	1.02

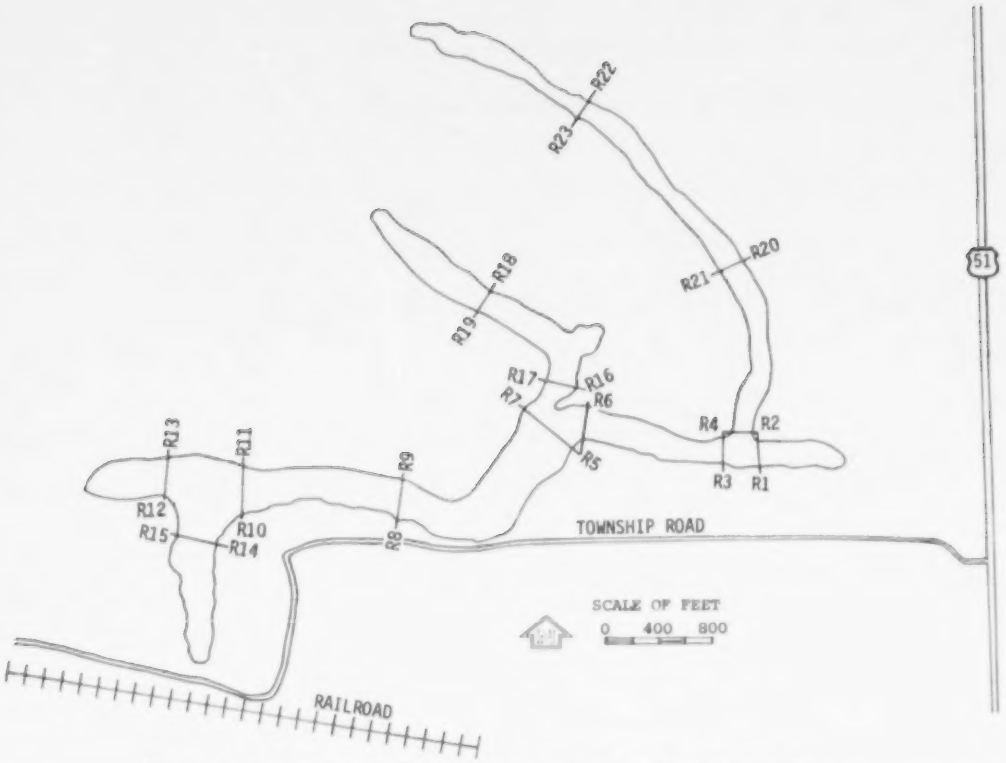

Figure 18. Old DuQuoin Pit range line locations.

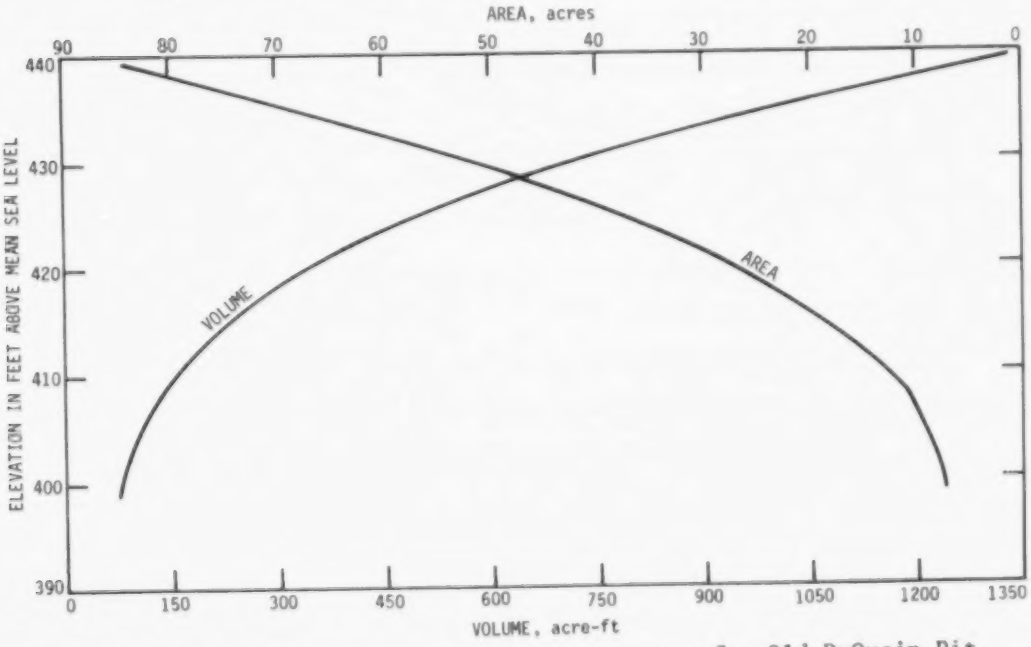

Figure 19. Stage-volume, stage-area curves for Old DuQuoin Pit.

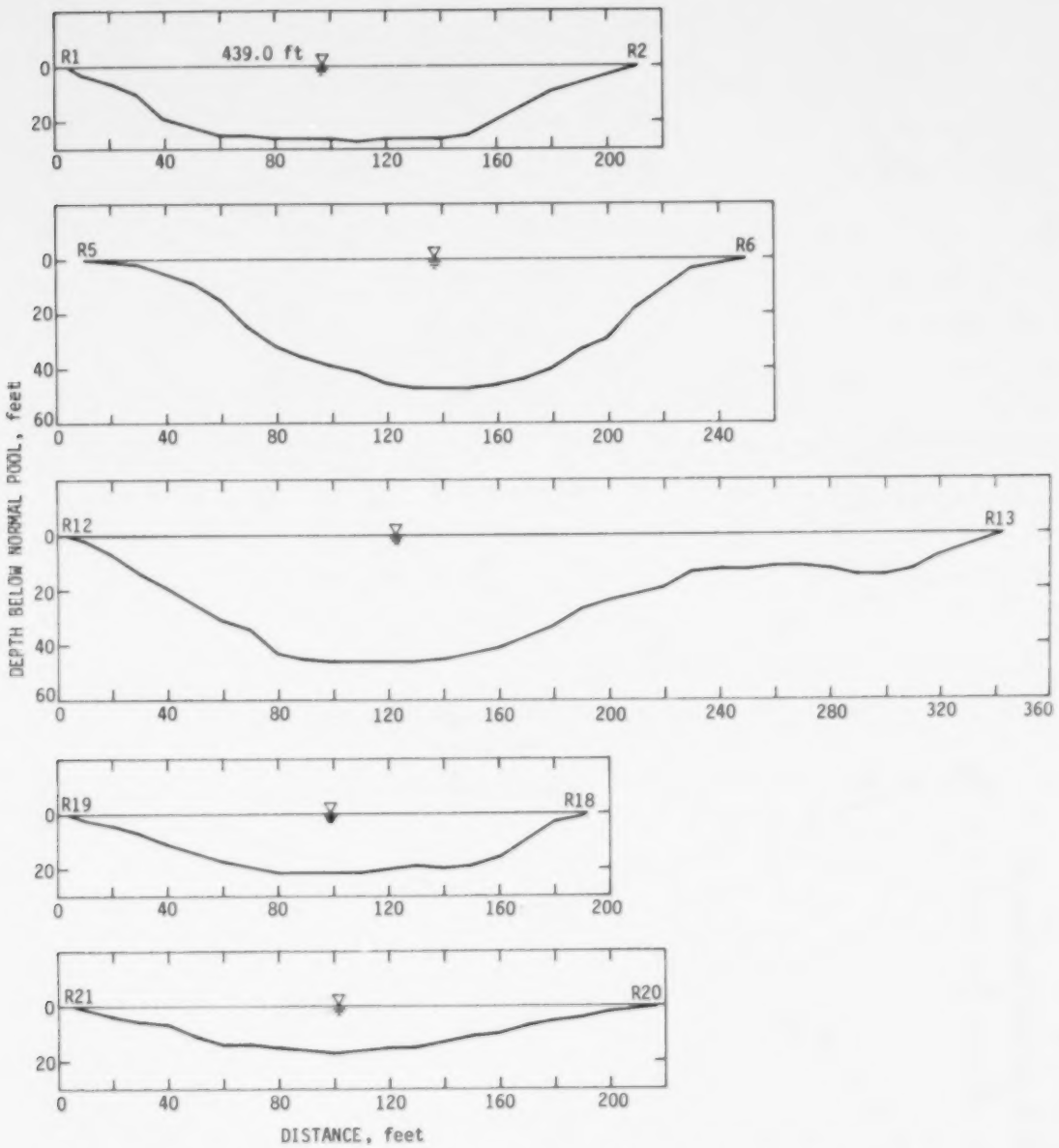

Figure 20. Representative cross sections of Old DuQuoin Pit.

Table 24. Chemical Analysis Data, Old DuQuoin Pit

Depth	Temp	DO	Field pH	Field alk	Conductivity at 25°C	TDS	Hard	Cl	F	SO_4	NO_3-N
November 1977											
0	10.2	10.4	8.2	91		2586	1220	41	0.49	1693	0.08
5	10.2	10.4									
10	10.2	10.4									
15	10.2	10.4	8.1	91		2562	1250	39	0.50	1705	0.04
20	10.2	10.4									
25	10.2	10.4									
30	10.2	7.2	8.0	91		2578	1250	41	0.49	1719	0.06
February 1978, 8 inch ice											
0	0.0	12.4	8.0	101	2880	2534	1300	42	0.46	1926	0.04
5	1.0	12.7			2888						
10	2.0	13.4			2890						
15	2.0	13.4			2890						
20	2.0	13.3			2890						
25	2.0	13.2	8.0	101	2890	2563	1260	42	0.44	1910	0.06
30	2.5	13.2			2856						
35	2.5	13.0			2856						
40	2.8	13.0			2855						
45	4.0	6.6	7.9	109	2916	2579	1270	41	0.42	1865	0.06
April 1978											
0	16.0	8.2	8.1	101	2541	2065	1030	39	0.4	1290	0.13
5	16.0	8.4			2541						
10	16.0	8.4			2541						
15	14.5	8.5			2500						
20	7.0	8.5			2682						
25	6.0	8.7	7.7	119	2754	2382	1190	44	0.4	1501	0.18
30	6.0	8.1			2754						
35	5.5	7.8			2945						
40	5.5	7.4			2945						
45	5.0	6.8			2983						
48	5.0	3.8	7.5	139	2983	2588	1280	45	0.4	1593	0.16

	November 1977			February 1978			April 1978		
	Surface	Middle	Bottom	Surface	Middle	Bottom	Surface	Middle	Bottom
Fe	0.12	0.18	0.19	0.02	0.08	0.20	0.05	0.05	0.05
Mn	0.09	0.14	0.22	0.00	0.01	0.08	0.07	0.15	0.35
Pb	0.08	0.07	0.07	0.14	0.14	0.13	ND	ND	ND
Cd	0.02	0.02	0.02	0.02	0.03	0.02	ND	ND	ND
Hg	0.90	0.19	0.65	0.54	0.78	0.96	0.07	0.28	0.14
K	4.6	4.5	4.5	4.6	4.6	4.6	5.6	6.3	6.6
Na	250	240	240	235	230	230	214	248	268
Cu	0.01	0.02	0.02	<0.01	0.03	0.01	0.01	0.02	0.03
Zn	0.03	0.10	0.04	0.01	0.12	0.07	ND	0.05	0.05
As	<0.001	<0.001	<0.001	<0.002	<0.002	<0.002	<0.001	<0.001	<0.001
Se	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Ag	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cr	ND	ND	ND	ND	ND	ND	ND	ND	ND
Ba	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
B	0.3	0.3	0.3	0.30	0.30	0.30	0.2	0.3	0.3

Note: Temperature, °Celsius; conductivity, μ mhos; Hg, μg/l; all other values except pH, mg/l

6 -- "East C" Streamline Mine

"East C" Streamline Mine is located in Section 32, T5S, R4W, Randolph County. The lake and surrounding property is owned by Southwestern Coal Company who opened the mine in July 1966 and closed it May 1974. The Herrin (No. 6) coal was mined with 5761M and 5561M shovels until 1969 when the 5561M was replaced with a 5560 bucket wheel excavator. The coal was overlain by 75 to 100 feet of overburden materials of which 20 to 40 feet was glacial clays and tills. The rock overburden consisted of interbedded layers of dark gray shale, limestone, and slate (14).

The general shape of the lake and locations of range lines where depth measurements were made are shown in figure 21. The area and volume of the lake at elevation 440 feet above mean sea level are 112.0 acres and 3488 acre-feet, respectively. Stage-volume and stage-area curves for the lake are presented in figure 22. The maximum measured and calculated average depths are 82 and 31.1 feet, respectively. Representative cross sections illustrating the lake profile are shown in figure 23.

The watershed of this lake extends to the west about 1 mile and to the north 1 mile. It covers about 2966 acres of which about 60 percent is strip mine land planted in grass and clover. The remainder is cultivated farm land. Because of the significant amount of farm land, a curve number (CN) value of 70 was used for simulated runoff calculations. Precipitation data from DuQuoin were used for the 20 years of interest.

On the basis of the calculated net runoff values and a groundwater contribution of 0.036 gpm/ft x 22,500 ft (the approximate combined length of the various lake segments), the yields presented in table 25 were determined.

Table 25. Estimated Yield Potential of "East C" Streamline Lake

	Yield (mgd) for given recurrence interval (yr)			
	1.1	*2*	*5*	*10*
Net surface yield	1.61	2.81	4.06	4.60
Groundwater contribution	1.17	1.17	1.17	1.17
Total	2.78	3.98	5.23	5.77

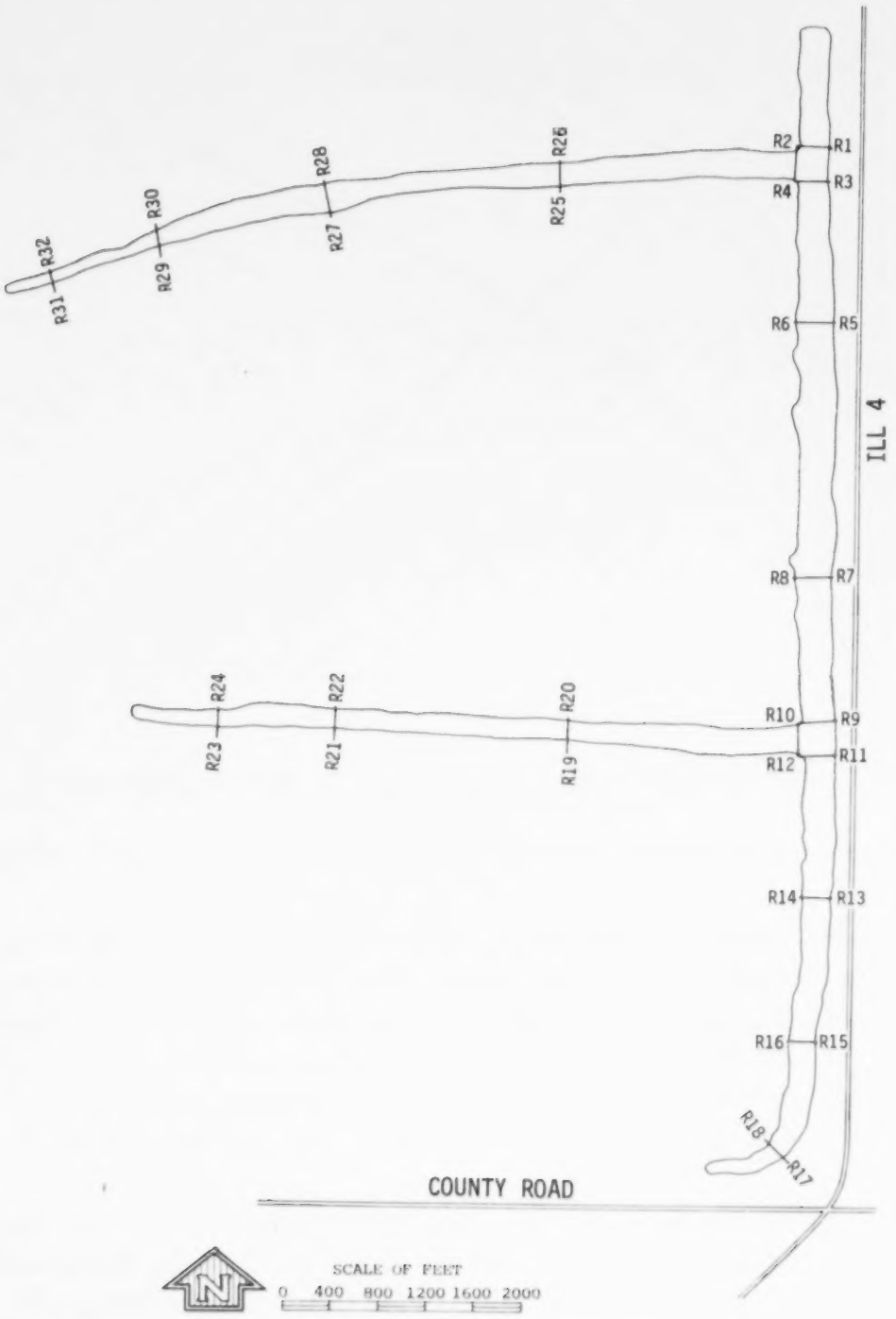

Figure 21. "East C" Streamline lake range line locations.

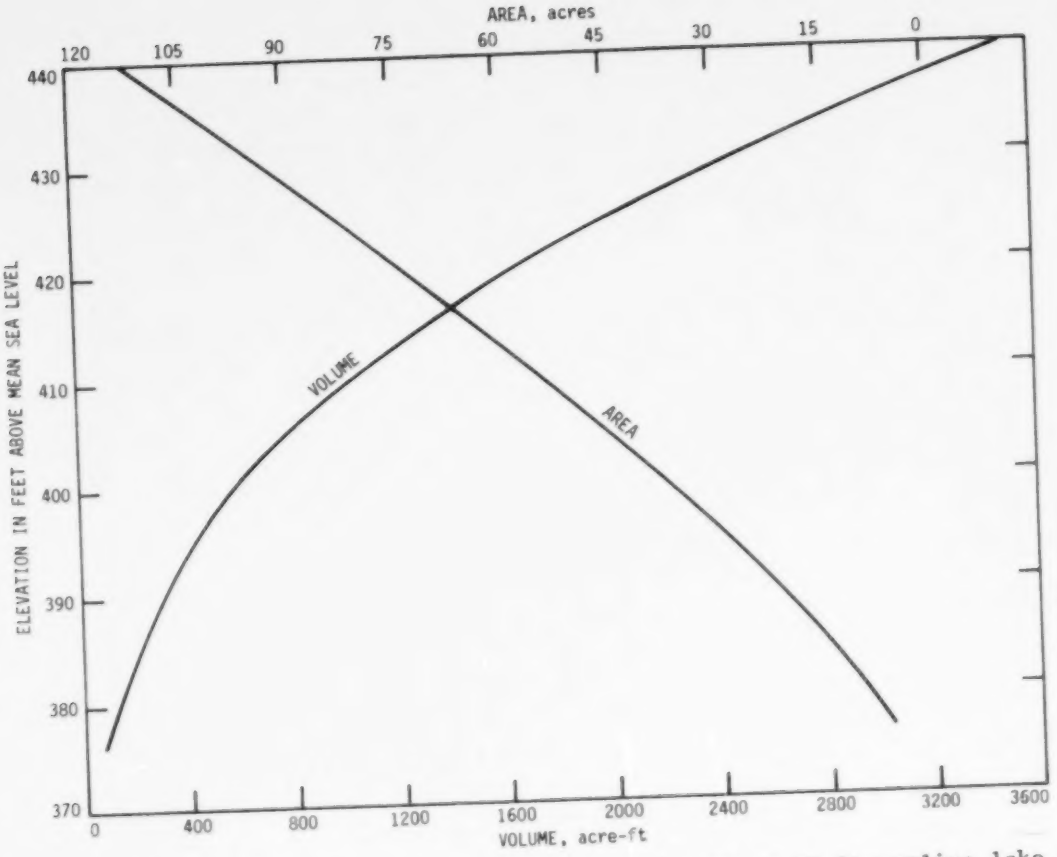

Figure 22. Stage-volume, stage-area curves for "East C" Streamline lake.

As noted earlier in the report, water level data were available for this lake from July 1975 through February 1978 (the period of time when the lake was filling). Water budget analyses of these data were attempted to determine the groundwater contribution to the lake during this period of time. For this analysis, precipation data from DuQuoin, pan evaporation data from Carlyle, and a CN of 70 were used. Table 26 summarizes the results.

During the very early periods, large runoff events occurred and the lake level rose at a faster rate than the water levels in the surrounding spoil. These spoil materials essentially had been dewatered during the mining activity. As a result, movement of water was from the lake into the

spoil (a negative groundwater contribution). During periods of very little or no runoff, the direction of flow reversed as the water levels in the spoil began to exceed those in the lake. These data are interesting but do not provide the type of information desired to determine groundwater yields to a lake under pumped conditions.

Chemical analysis data for water samples collected November 1977 and February and April 1978 are presented in table 27.

Table 26. Water Budget Analysis of "East C" Streamline Lake and Watershed

Date	*Lake level (MSL)*	*Lake volume (ac-ft)*	*Precip. (inches)*	*Runoff (inches)*	*Lake evap. (inches)*	*Groundwater contrib. (gpm/ft)*
7/26/75	402.63	680				
8/17/75	406.13	840	5.89	1.9	4.31	-0.14
2/3/76	410.13	1040	14.50	8.6	8.99	-0.12
4/27/76	421.12	1720	5.99	2.0	4.23	0.02
5/28/76	422.23	1840	1.80	0.1	5.66	0.04
6/5/76	422.12	1840	3.07	0.6	0.88	-0.20
6/23/76	422.72	1860	0.47	0	4.45	0.03
7/6/76	421.21	1760	1.13	0	2.79	-0.07
7/19/76	422.62	1860	0.38	0	3.95	0.10
7/31/76	424.70	2040	3.75	1.0	3.46	-0.06
9/9/76	427.00	2240	3.35	1.0	8.22	0
10/7/76	427.52	2250	2.27	0.1	3.95	0
10/26/76	426.61	2200	1.86	0.1	1.91	-0.04
10/25/77	439.55	3440	38.94		35.49	
11/8/77	439.83	3480	1.48	0	0.45	0.02
11/30/77	440.20	3520	2.58	0.2	0.45	-0.01
12/13/77	442.00	3700	3.44	0.5	0	0.02
1/4/78	443.29	3830	0.59	0	0	0.06
1/23/78	443.70	3870	1.05	0	0	0.02
2/6/78	443.80	3880	0.19	0	0	0.01

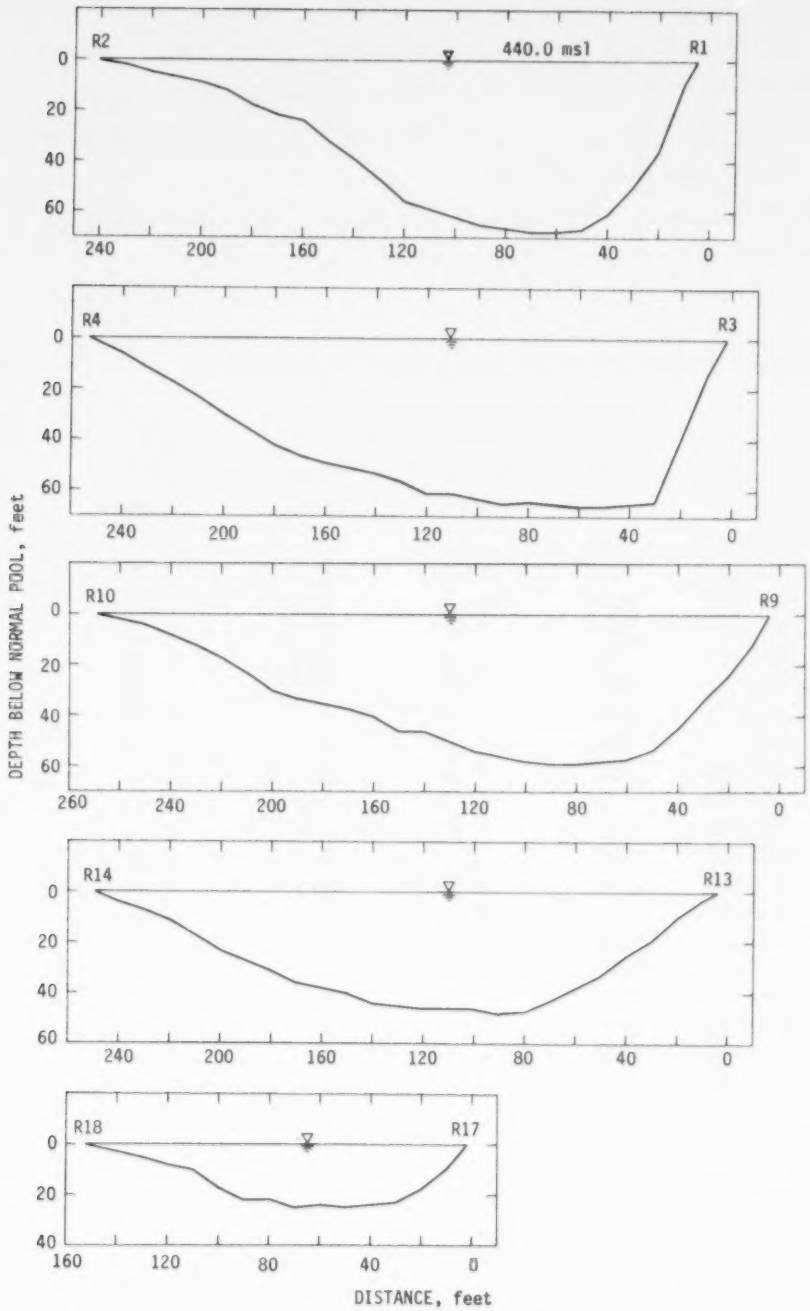

Figure 23a. Representative cross sections of "East C" Streamline lake.

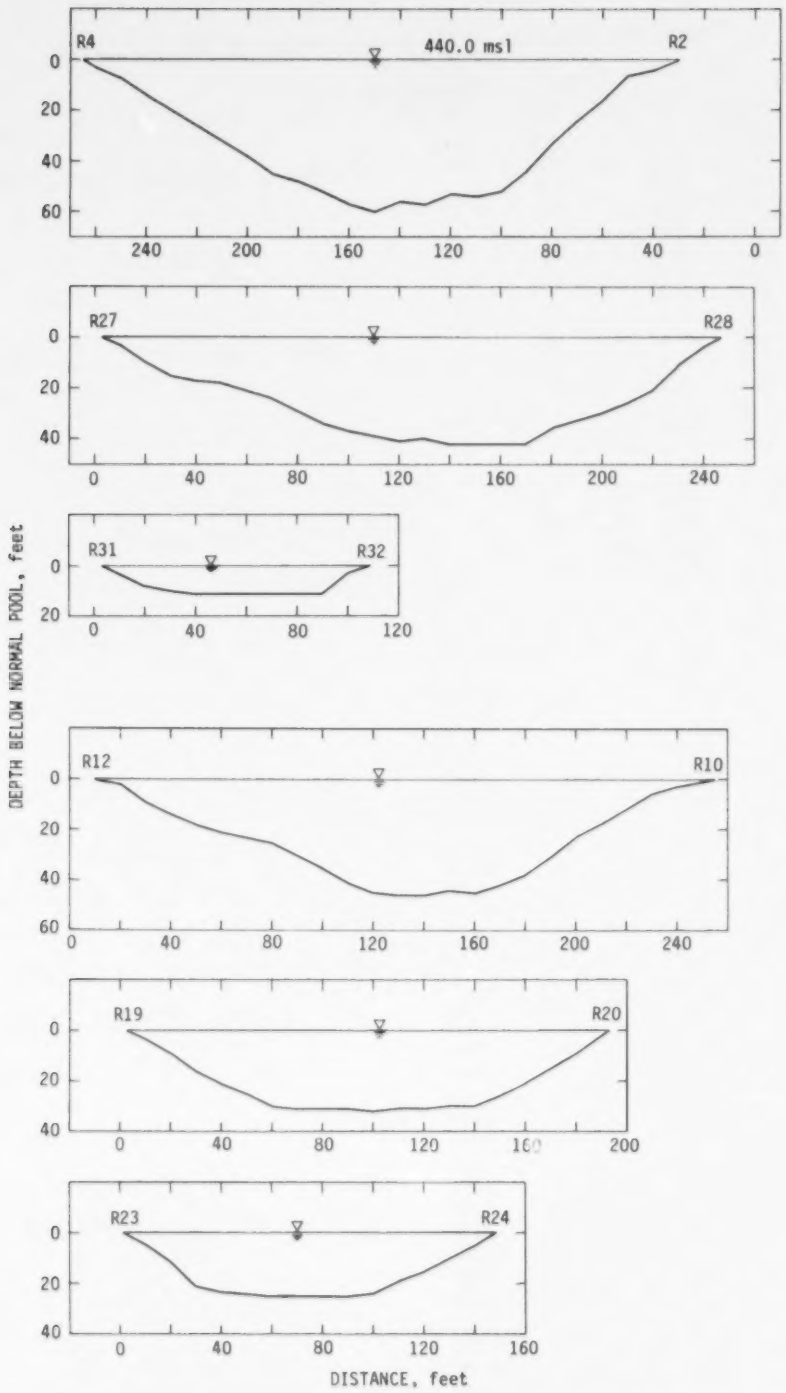

Figure 23b. Representative cross sections of "East C" Streamline lake.

Table 27. Chemical Analysis Data, "East C" Streamline Lake

Depth	Temp	DO	Field pH	Field alk	Conductivity at 25°C	TDS	Hard	Cl	F	SO_4	NO_3-N
November 1977											
0	11.0	9.7	8.0	225		2868	1224	38	0.58	1826	0.09
5	11.0	9.5									
10	11.2	9.0									
15	11.2	9.0									
20	11.2	9.0									
25	11.3	8.8									
30	11.3	8.8									
35	11.5	8.7									
40	11.5	8.6	8.0	220		2870	1200	27	0.58	1856	0.10
45	11.5	0.9									
50	11.3	0.7									
55	11.0	0.6									
60	11.0	0.4									
65	11.0	0.4									
70	11.2	0.3									
75	12.0	0.3									
80	12.0	0.2	7.0	740		5978	2125	161	0.79	3247	0.11
February 1978, 6 inch ice											
0	0.5	14.2	7.85	222	2670	2670	1160	26	1.05	1917	0.24
5	1.0	14.4			3010						
10	1.0	14.6			3150						
15	1.0	14.2			3150						
20	1.0	14.1			3150						
25	1.0	14.1			3150						
30	1.0	14.0			3150						
35	1.0	13.6			3185						
40	1.5	13.5			3182						
45	2.0	12.6	7.75	227	3230	2685	1160	27	0.64	1984	0.21
50	2.0	12.0			3315						
55	2.5	11.6			3326						
60	2.5	11.4			3360						
65	6.2	1.6			3519						
70	8.5	0.6			5328						
75	9.5	0.3			5880						
80	11.0	0.0			7370						
83	11.8	0.0	6.75	785	7260	5903	2120	155	0.79	3483	0.12
April 1978											
0	15.1	12.4	8.55	152	2349	1829	800	19	0.40	1138	0.24
5	15.1	12.9			2349						
10	15.1	12.7			2349						
15	14.9	12.1			2343						
20	10.2	9.4			2629						
25	5.0	7.3			2983						
30	4.0	7.0			3094						
35	4.0	6.8			3159						
40	4.0	6.6			3232						
45	4.0	6.1	7.25	255	3248	2768	1200	30	0.50	1663	0.44
50	4.0	5.8			3370						
55	4.0	5.6			3410						
60	4.0	5.2			3499						
65	4.5	4.3			3680						
70	5.5	2.9			3860						
75	8.0	0.1			5256						
80	10.0	0.1			5920						
85	11.0	0.1	6.80	659	6200	5298	2050	114	0.70	3083	0.17

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Table 27. Concluded

	November 1977			February 1978			April 1978		
	Surface	*Middle*	*Bottom*	*Surface*	*Middle*	*Bottom*	*Surface*	*Middle*	*Bottom*
Fe	0.31	0.34	21.10	0.18	0.06	24.3	0.05	0.09	20.2
Mn	0.69	0.75	3.40	0.66	0.81	4.65	0.51	1.14	5.9
Pb	0.07	0.08	0.08	0.11	0.11	0.11	ND	ND	ND
Cd	0.02	0.02	0.04	0.02	0.02	0.03	ND	ND	ND
Hg	0.08	0.22	0.74	0.80	0.66	0.64	0.16	0.23	0.30
K	8.20	8.10	8.40	8.5	8.5	12.8	8.8	11.0	17.7
Na	220	400	1000	305	310	425	261	382	875
Cu	0.01	0.03	0.08	<0.01	0.01	0.04	0.01	0.02	0.04
Zn	0.11	0.10	0.20	0.02	0.05	0.27	ND	0.05	0.18
As	<0.001	<0.001	0.008	<0.002	<0.002	<0.002	<0.001	<0.001	0.01
Se	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Ag	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cr	ND	ND	ND	ND	ND	ND	ND	ND	ND
Ba	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.10	<0.1
B	0.5	0.5	1.3	0.5	0.5	1.4	0.30	0.50	1.2

Note: Temperature, °Celsius; conductivity, μ mhos; Hg, μg/l; all other values except pH, mg/l

7 -- Red Ray Lake

Red Ray lake is located in Section 33, T1S, R7W, St. Clair County. The lake and surrounding property are owned by Peabody Coal Company who opened the mine in September 1957 and closed it in January 1965. The Herrin (No. 6) coal was mined with a 5760 M 70 cubic yard shovel. The coal was overlain by less than 50 feet of overburden materials, of which almost all was glacial clay, till, and sand (14).

The general shape of the lake and locations of range lines where depth measurements were taken are shown in figure 24. The area and volume of the lake at elevation 392 feet above mean sea level are 5.83 acres and 110 acre-feet, respectively. Stage-volume and stage-area curves for the lake are presented in figure 25. The maximum measured and calculated average depths are 40 and 18.9 feet, respectively. Representative cross sections illustrating the general lake profile are shown in figure 26.

The watershed for this lake extends some 2½ miles northwest and includes the southern edge of the village of Freeburg. The watershed covers approximately 765 acres of which about 20 percent is strip mine land. Lemon Branch, a perennial stream, lies within the watershed and drains through Red Ray lake. Because of the high percentage of farm land in the watershed, a curve number (CN) of 70 was selected for runoff calculation. Precipitation data from Sparta were used to simulate the 20 year period of net runoff.

On the basis of the calculated net runoff values and a groundwater contribution of 0.036 gpm/ft x 1700 feet (the approximate length of the lake), the estimated yields presented in table 28 were determined.

Chemical analysis data for water samples collected November 1977 and February and April 1978 are presented in table 29.

Table 28. Estimated Yield Potential of Red Ray Lake

	Yield (mgd) for given recurrence interval (yr)			
	1.1	*2*	*5*	*10*
Net surface yield	0.43	0.79	1.02	1.14
Groundwater contribution	0.09	0.09	0.09	0.09
Total	0.52	0.88	1.11	1.23

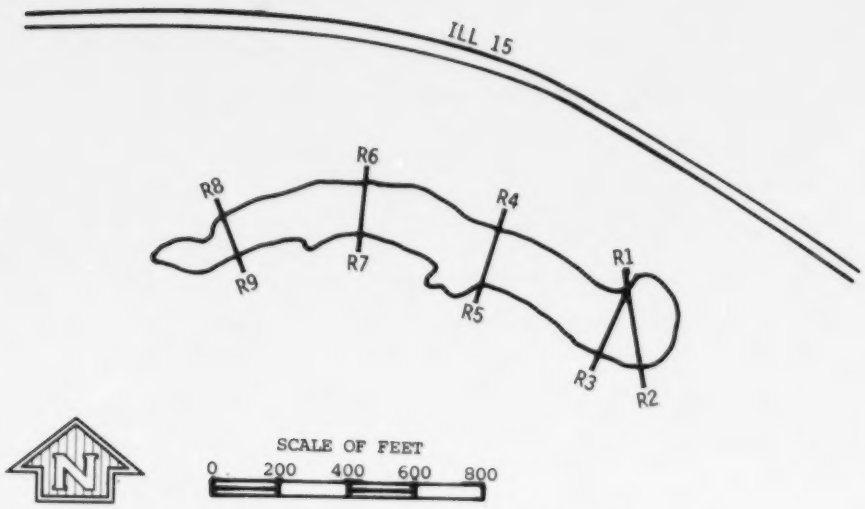

Figure 24. Red Ray lake range line locations.

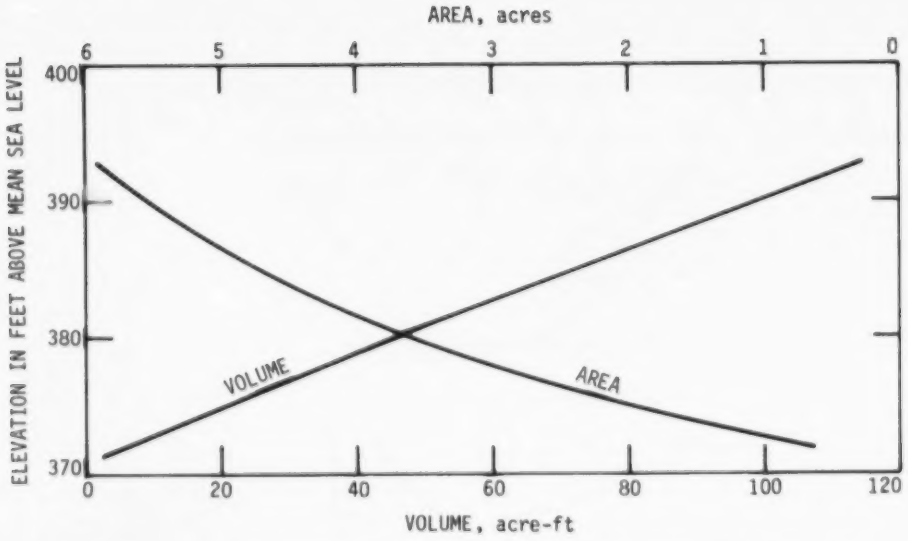

Figure 25. Stage-volume, stage-area curves for Red Ray lake.

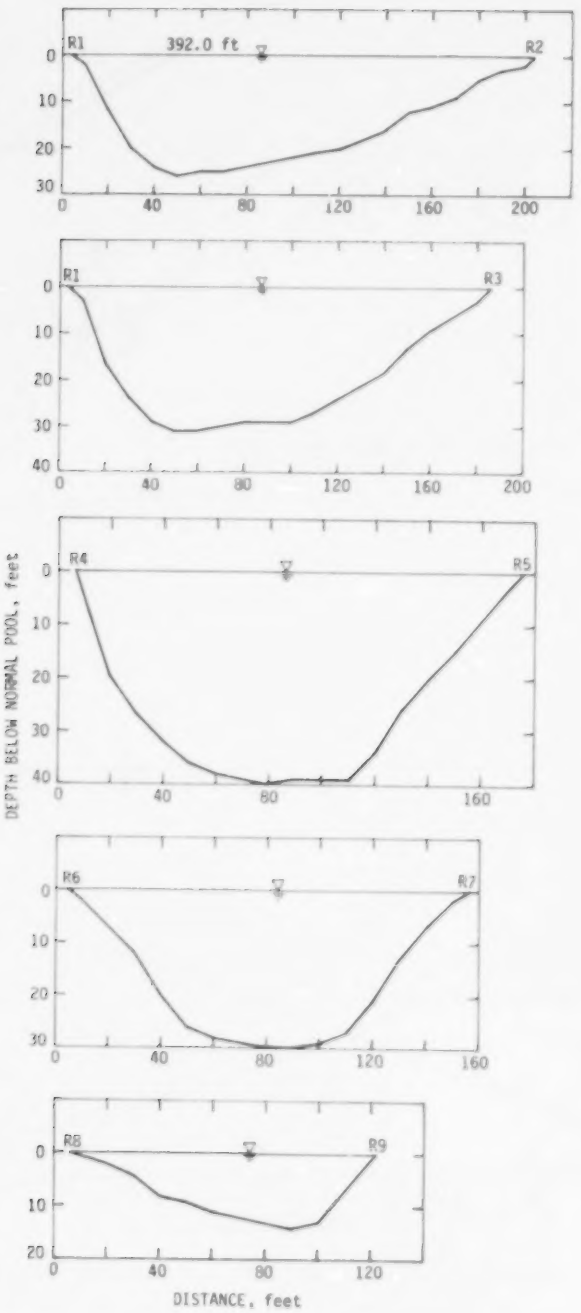

Figure 26. Representative cross sections of Red Ray lake.

Table 29. Chemical Analysis Data, Red Ray Lake

Depth	Temp	DO	Field pH	Field alk	Conductivity at 25°C	TDS	Hard	Cl	F	SO_4	NO_3-N
November 1977											
0	11.2	10.2	8.1	189		688	475	23	0.34	342	0.06
2	11.2	10.0									
4	11.2	9.8									
6	11.2	9.7									
8	11.2	9.4									
10	11.2	9.3									
12	11.2	9.1	8.0	192		818	470	44	0.36	332	0.06
14	11.2	9.1									
16	11.2	8.8									
18	12.8	1.6									
20	13.5	1.4									
22	13.8	0.5	7.5	285		1192	715	24	0.39	629	0.02
February 1978, 6 inch ice											
0	3.0	16.9	8.4	167	797	539	400	28	0.29	157	1.03
2	3.0	15+									
4	3.0	15+									
6	4.5	15+			960						
8	5.0	11.8									
10	5.2	10.8			1178						
12	5.5	10.2	7.2	215		748	504	25	0.29	297	0.71
14	6.0	7.6									
16	6.5	3.0			1586						
18	8.0	1.6									
20	8.5	1.2			2304						
22	9.0	1.0									
24	9.0	0.1	7.1	381	2386	1618	996	24	0.34	872	0.55
April 1978											
0	19.5	21.0	9.8	134	672	384	246	22	0.3	158	0.40
2	19.0	15+			678						
4	17.5	15+			702						
6	15.0	15+			738						
8	10.0	15.0			897						
10	7.6	4.2			1029						
12	6.0	3.6			1224						
14	7.0	3.1	7.2	215	1490	760	484	25	0.3	372	1.16
16	8.0	2.7			2044						
18	8.5	2.6			2232						
20	8.5	2.6			2304						
25	9.0	2.2			2414						
30	9.0	1.5	7.0	467	2414	1876	1180	27	0.4	956	0.13

	November 1977			February 1978			April 1978		
	Surface	Middle	Bottom	Surface	Middle	Bottom	Surface	Middle	Bottom
Fe	0.26	0.16	0.20	0.20	0.08	1.62	0.07	0.09	2.02
Mn	0.46	0.43	5.44	0.22	1.47	6.69	0.07	1.58	9.2
Pb	0.02	0.02	0.02	0.08	0.08	0.17	ND	ND	ND
Cd	0.02	0.02	0.03	0.02	0.02	0.02	ND	ND	ND
Hg	0.44	0.22	0.32	0.73	0.53	0.59	0.25	0.17	0.21
K	4.6	4.5	4.8	4.9	4.7	4.7	4.6	5.5	6.7
Na	66	64	100	40	50	120	32	64	150
Cu	0.02	0.02	0.02	<0.01	0.02	0.03	ND	0.03	0.03
Zn	0.08	0.04	0.05	0.07	0.06	0.17	ND	ND	0.09
As	0.001	0.001	0.003	0.006	0.005	0.008	0.002	0.002	0.09
Se	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Ag	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cr	ND	ND	ND	ND	ND	ND	ND	ND	ND
Ba	<0.1	<0.1	<0.1	<0..	<0.1	<0.1	<0.1	<0.1	<0.1
B	0.3	0.3	0.5	0.2	0.3	0.6	0.1	0.3	0.7

Note: Temperature, °Celsius; conductivity, μ mhos; Hg, μg/l; all other values except pH, mg/l

8 -- Seminole Lake

Seminole lake is located in Section 2, T3S, R7W, St. Clair County. The lake and surrounding property is owned by Peabody Coal Company who opened the mine in October 1950 and closed it in March 1954. The Herrin (No. 6) coal was mined with a 5480 Marion 20 cubic yard shovel and 7800 Marion 30 cubic yard dragline. The coal was overlain by 50 to 75 feet of overburden of which only 20 to 30 feet was glacial materials. The rock overburden consisted of black slaty shale overlain by interbedded gray shale, clay, and limestone beds (14).

The general shape of the lake and locations of range lines where depth measurements were taken are shown in figure 27. The area and volume of the lake at elevation 416 feet above mean sea level are 7.81 acres and 97 acre-feet, respectively. Stage-volume and stage-area curves for the lake are presented in figure 28. The maximum measured and calculated average depths are 23 and 12.4 feet, respectively. Representative cross sections illustrating the general lake profile are shown in figure 29.

The watershed of this lake is contained within ½ mile of the lake and covers about 77 acres. Approximately 50 percent is spoil material and is grown up in shrubs and small trees. The remainder is cultivated farm land. A curve number (CN) value of 70 was selected for simulated runoff calculations. Precipitation data from Sparta were used for the 20 years simulation.

On the basis of the calculated net runoff values and a groundwater contribution of 0.036 gpm/ft x 2700 feet (the combined total length of the lake) the estimated yields presented in table 30 were determined.

Chemical analysis data for water samples collected November 1977 and February and April 1978 are presented in table 31.

Table 30. Estimated Yield Potential of Seminole Lake

	Yield (mgd) for given recurrence interval (yr)			
	1.1	*2*	*5*	*10*
Net surface yield	0.04	0.08	0.11	0.12
Groundwater contribution	0.14	0.14	0.14	0.14
Total	0.18	0.22	0.25	0.26

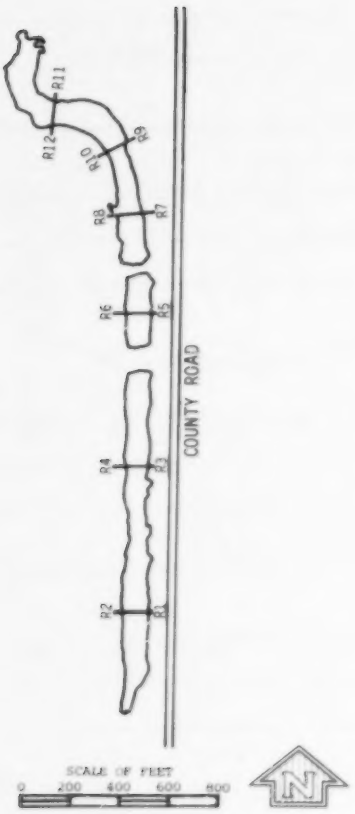

Figure 27. Seminole lake range line locations.

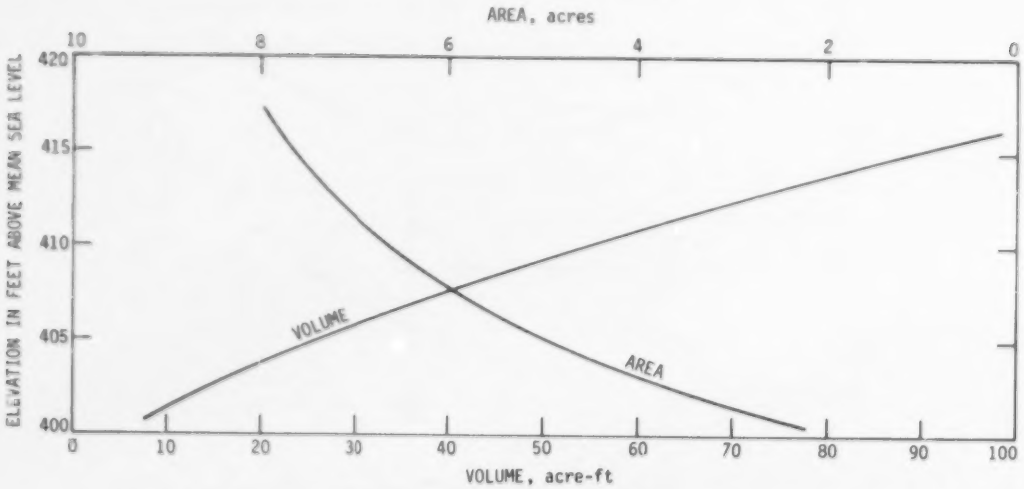

Figure 28. Stage-volume, stage-area curves for Seminole lake.

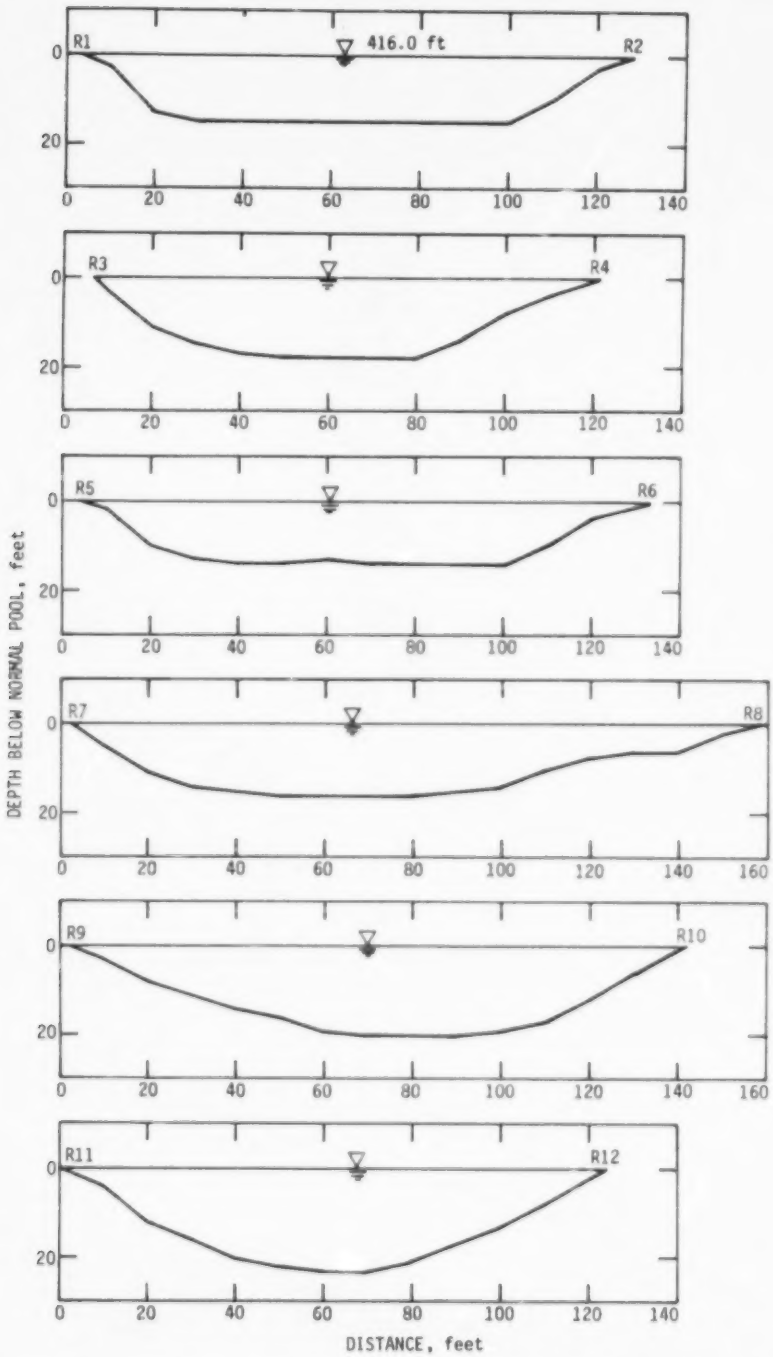

Figure 29. Representative cross sections of Seminole lake.

Table 31. Chemical Analysis Data, Seminole Lake

Depth	Temp	DO	Field pH	Field alk	Conductivity at 25°C	TDS	Hard	Cl	F	SO_4	NO_3-N
November 1977											
0	12.0	10.1	8.2	139		1746	1175	5	0.42	1297	0.02
2	12.0	10.1									
4	12.0	10.2									
6	12.0	10.2									
8	12.0	10.2									
10	12.0	10.2	8.2	139		1820	1190	4	0.43	1294	0.02
12	12.0	10.2									
14	12.0	10.2									
16	12.0	10.2									
18	12.0	10.0									
20	12.2	1.2	8.2	136		1832	1140	3	0.43	1280	0.04
February 1978, 6 inch ice											
0	0.2	15.8	8.1	164	2196	1833	1240	4	0.42	1370	0.12
2	0.5	15+			2172						
4	4.0	15+			2268						
6	5.2	15+			2355						
8	5.5	15.0			2325						
10	5.5	12.5	7.8	177	2325	2021	1370	6	0.36	1506	0.24
12	5.5	12.0			2356						
14	5.5	8.8			2356						
16	6.0	5.2			2479						
18	7.0	3.1	7.3	210	2533	2158	1420	5	0.37	1596	0.21
April 1978											
0	15.0	8.3	8.1	66	544	333	212	2	0.4	187	0.27
2	15.0	8.3			544						
4	7.5	8.4			2822						
6	5.0				2732						
8	4.5				2752						
10	4.0	11.8	7.4	237	2786	2148	1445	6	0.4	1327	0.27
12	4.0				2786						
14	4.0				2786						
16	4.0				3013						
18	4.0	10.1	7.3	247	3175	2234	1500	6	0.4	1377	0.26

	November 1977			February 1978			April 1978		
	Surface	Middle	Bottom	Surface	Middle	Bottom	Surface	Middle	Bottom
Fe	0.15	0.15	0.22	0.03	0.05	0.20	0.29	0.29	0.47
Mn	0.27	0.24	0.21	0.06	0.08	0.42	0.13	0.92	1.60
Pb	0.08	0.08	0.08	0.14	0.14	0.13	ND	ND	ND
Cd	0.03	0.03	0.03	0.02	0.02	0.03	ND	ND	ND
Hg	0.85	0.56	0.44	0.41	0.45	0.67	0.03	0.14	0.20
K	4.2	4.2	4.1	4.4	4.2	4.3	1.8	5.6	5.8
Na	80	80	80	65	65	70	19	83	85
Cu	0.01	0.02	0.02	<0.01	0.02	0.02	ND	0.01	0.02
Zn	0.04	0.06	0.05	0.02	0.07	0.08	ND	0.03	0.06
As	0.001	0.001	0.001	<0.002	<0.002	0.003	0.001	0.001	0.001
Se	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Ag	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cr	ND	ND	ND	ND	ND	ND	ND	ND	ND
Ba	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
B	0.3	0.3	0.3	0.3	0.3	0.3	0.1	0.3	0.4

Note: Temperature, °Celsius; conductivity, μ mhos; Hg, μg/l; all other values except pH, mg/l

9 -- River King No. 6 Lake

River King No. 6 is located in Section 28, T3S, R6W, St. Clair County. The lake and surrounding property is owned by Peabody Coal Company who opened the mine in January 1967 and closed it in December 1970. The Herrin (No. 6) coal was mined with a 3850B 140 cubic yard shovel. The coal was overlain by 50 to 75 feet of overburden of which about 20 to 25 feet was glacial clays and tills. The rock overburden consisted of black slaty shale overlain by interbedded gray shale, clay, and limestone beds (14).

The general shape of the lake and locations of range lines where depth measurements were taken are shown in figure 30. The area and volume of the lake at elevation 429 feet above mean sea level are 30.72 acres and 620 acre-feet, respectively. Stage-volume and stage-area curves for the lake are presented in figure 31. The maximum measured and calculated average depths are 55 and 20.2 feet, respectively. Representative cross sections illustrating the general lake profile are shown in figure 32.

The watershed of this lake covers approximately 258 acres of which about 90 percent is strip mine land covered with grass and small trees. The remaining 10 percent is cultivated farm land. The relatively poor drainage characteristics of the spoil materials as compared with those at Middle Grove were assumed to offset the increased drainage from the small agricultural portion of the watershed. A curve number (CN) value of 60 was selected for simulated runoff calculations. Precipitation data from Sparta were used for the 20 years of interest.

On the basis of the calculated net runoff values and a groundwater contribution of 0.036 gpm/ft x 4100 ft (the approximate combined length of the various lake sections), the yields presented in table 32 were determined.

Chemical analysis data for water samples collected December 1977 and February and April 1978 are presented in table 33.

Table 32. Estimated Yield Potential of River King No. 6 Lake

	Yield (mgd) for given recurrence interval (yr)			
	1.1	*2*	*5*	*10*
Net surface yield	0.06	0.17	0.25	0.29
Groundwater contribution	0.21	0.21	0.21	0.21
Total	0.27	0.38	0.46	0.50

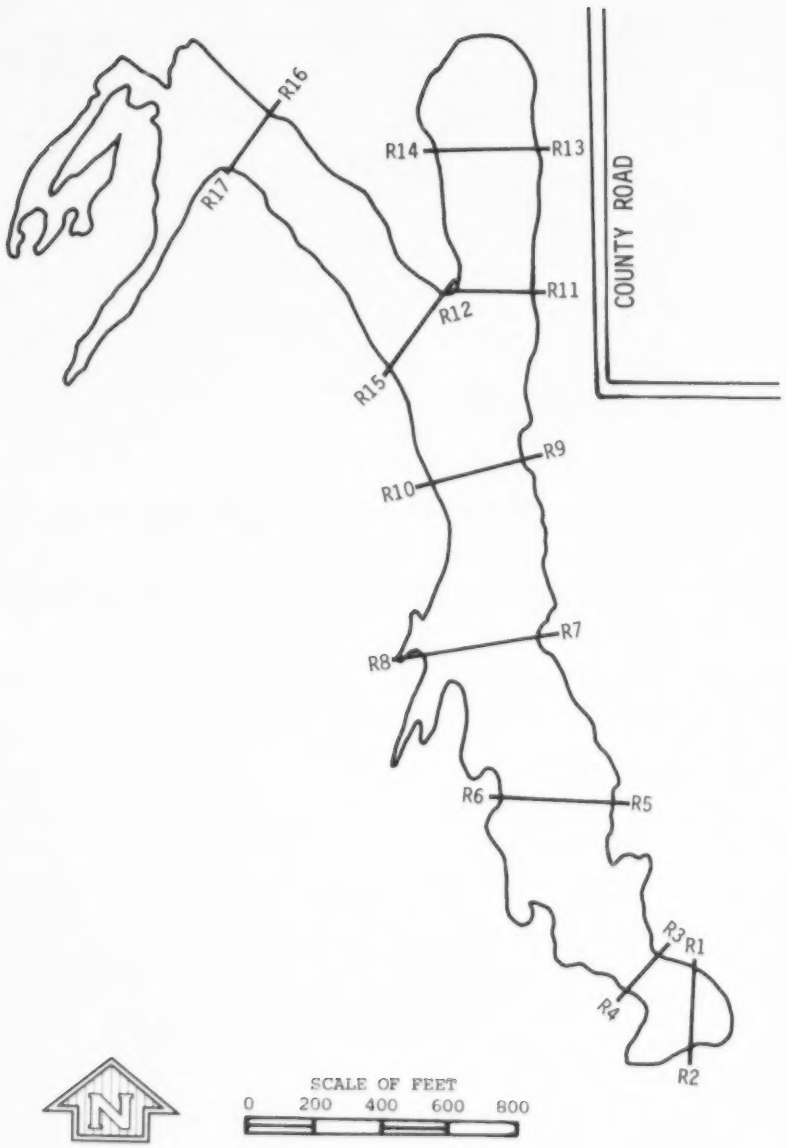

Figure 30. River King No. 6 lake range line locations.

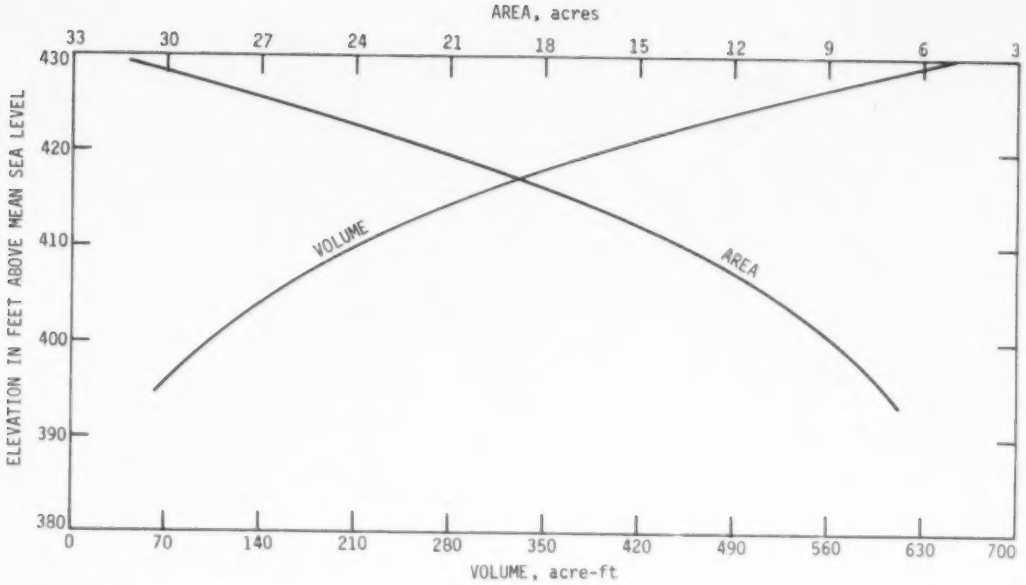

Figure 31. Stage-volume, stage-area curves for River King No. 6 lake.

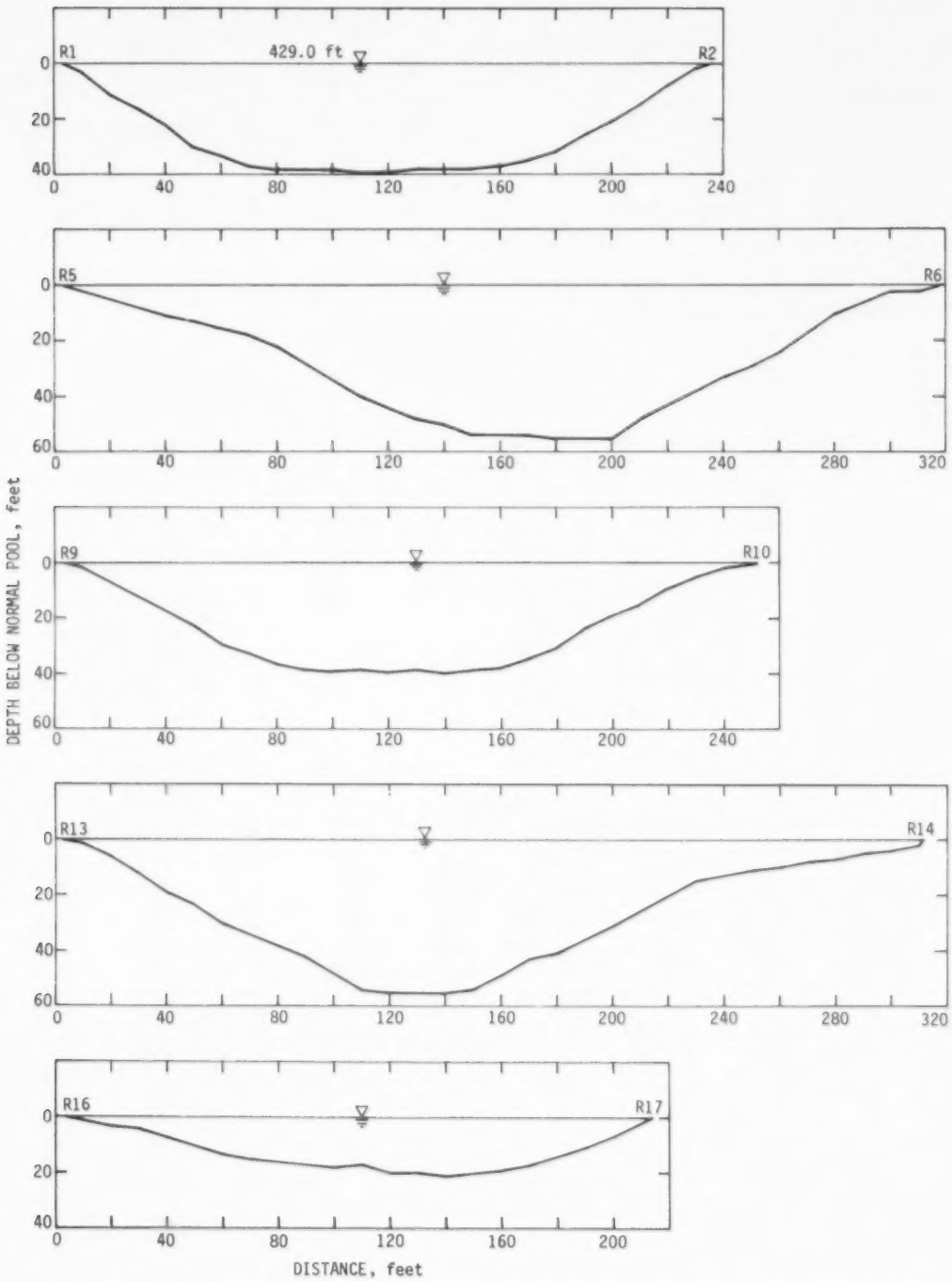

Figure 32. Representative cross sections of River King No. 6 lake.

Table 33. Chemical Analysis Data, River King No. 6 Lake

Depth	Temp	DO	Field pH	Field alk	Conductivity at 25°C	TDS	Hard	Cl	F	SO_4	NO_3-N
December 1977											
0	2.3	15.0	8.1	131		1686	707	19	0.46	960	0.14
5	2.3	15.0									
10	2.3	15.0									
15	2.3	15.0									
20	2.3	15.0	8.1	131		1668	720	18	0.47	962	0.11
25	2.3	15.0									
30	2.3	15.0									
35	2.3	15.0									
40	2.3	15.0	8.1	136		1706	753	19	0.46	981	0.12
February 1978, 7 inch ice											
0	1.0	14.4	8.3	131	2100	1644	720	46	0.46	1040	0.21
5	2.8	14.4			2075						
10	3.0	14.4			2075						
15	3.0	14.4									
20	3.0	14.5			2158						
25	3.0	14.4	8.3	136		1674	720	46	0.58	1124	0.17
30	3.0	14.2			2158						
35	3.0	14.2									
40	3.0	14.2			2158						
45	3.0	4.1			2158						
50	3.2	2.4	8.3	144	2158	1666	740	46	0.44	1101	0.29
April 1978											
0	17.0	9.0	8.3	126	1947	1347	603	39	0.4	813	0.16
5	17.0	9.0			1947						
10	17.0	9.1			1947						
15	11.5	9.6			1995						
20	7.2	9.4	8.3	129	2160	1386	613	39	0.4	829	0.18
25	7.0	9.4			2123						
30	6.0	9.5			2142						
35	6.0	9.4			2142						
40	5.5	7.8	7.8	145	2170	1549	690	44	0.4	932	0.49

	December 1977			February 1978			April 1978		
	Surface	Middle	Bottom	Surface	Middle	Bottom	Surface	Middle	Bottom
Fe	0.22	0.25	0.32	0.09	0.04	0.06	0.09	0.06	0.07
Mn	0.07	0.09	0.06	0.07	0.08	0.05	0.06	0.04	0.07
Pb	0.07	0.07	0.05	0.13	0.14	0.13	ND	ND	ND
Cd	0.03	0.03	0.02	0.01	0.02	0.02	ND	ND	ND
Hg	0.26	0.22	0.54	0.75	0.54	0.49	0.11	0.11	0.27
K	3.3	5.4	3.6	3.3	3.3	3.2	3.8	3.8	4.0
Na	172	168	168	205	205	210	192	196	224
Cu	0.01	0.02	0.02	<0.01	0.02	0.02	0.01	0.01	0.02
Zn	0.02	0.04	0.03	0.01	0.05	0.06	0.01	0.03	0.03
As	0.001	0.001	0.001	<0.002	<0.002	<0.002	<0.001	<0.001	<0.001
Se	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Ag	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cr	ND	ND	ND	ND	ND	ND	ND	ND	ND
Ba	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
B	0.5	0.5	0.5	0.5	0.5	0.5	0.4	0.4	0.5

Note: Temperature, °Celsius; conductivity, μmhos; Hg, μg/l; all other values except pH, mg/l

10 -- Coal City Area No. 1 Lake

Coal City Area No. 1 lake is located in Sections 31 and 32, T33N, R9E, Will County. The lake and surrounding property now is owned by the Coal City Sportsman Club. The mine was opened by Peabody Coal Company in March 1928 and closed in late 1950. The Colchester (No. 2) coal was mined with 5480M 6 cubic yard and 5480M 17 cubic yard draglines. The coal was overlain by less than 50 feet of overburden of which about half was glacial sands and clays. The rock overburden consisted of the Francis Creek shale which was around 20 feet thick (15).

The general shape of the lake and locations of range lines where depth measurements were taken are shown in figure 33. The area and volume of the lake at elevation 543 feet above mean sea level are 70.74 acres and 1659 acre-feet, respectively. Stage-volume and stage-area curves for the lake are presented in figure 34. The maximum measured and calculated average depths are 54 and 23.4 feet, respectively. Representative cross sections illustrating the general lake profile are shown in figure 35.

The watershed of this lake extends some 4 miles to the east and covers approximately 2016 acres. About 70 percent of the watershed consists of old strip mine lands and associated water bodies. The remaining 30 percent is relatively flat farm land or low land marshy areas. A curve number (CN) value of 60 was selected for runoff calculations as it was felt that the relatively rugged terrain of the spoil would offset the anticipated increased runoff from the farm land portion of the watershed. Precipitation data from Kankakee were used for the selected 20 years of simulated runoff.

On the basis of the calculated net runoff values and a groundwater contribution of 0.036 gpm/ft x 12,000 ft (the approximate length of the lake), the estimated yields presented in table 34 were determined.

Chemical analysis data for water samples collected November 1977 and February and April 1978 are presented in table 35.

Table 34. Estimated Yield Potential of Coal City Area No. 1 Lake

	Yield (mgd) for given recurrence interval (yr)			
	1.1	*2*	*5*	*10*
Net surface yield	0.49	1.07	1.54	1.74
Groundwater contribution	0.62	0.62	0.62	0.62
Total	1.11	1.69	2.16	2.36

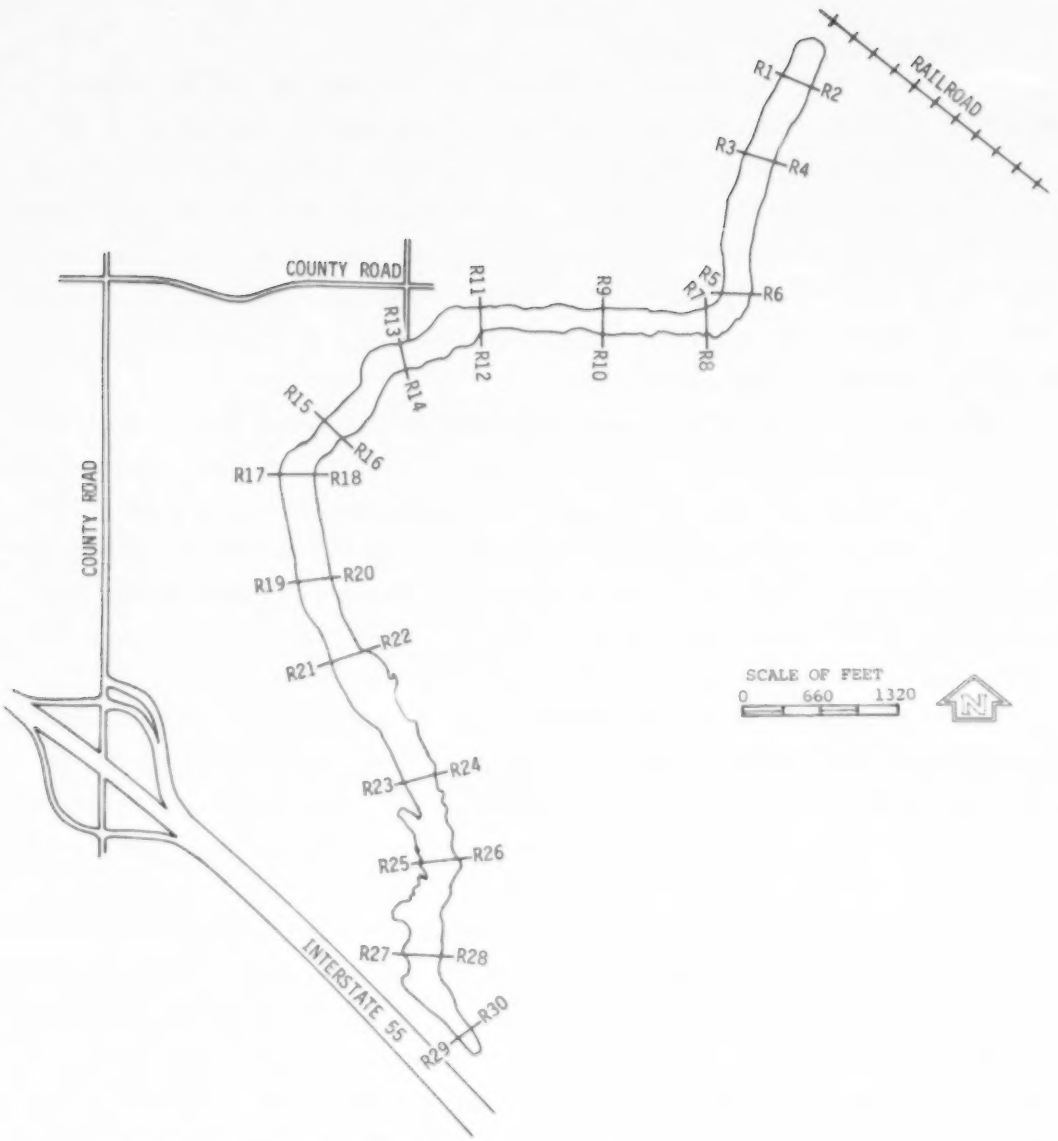

Figure 33. Coal City Area No. 1 lake range line locations.

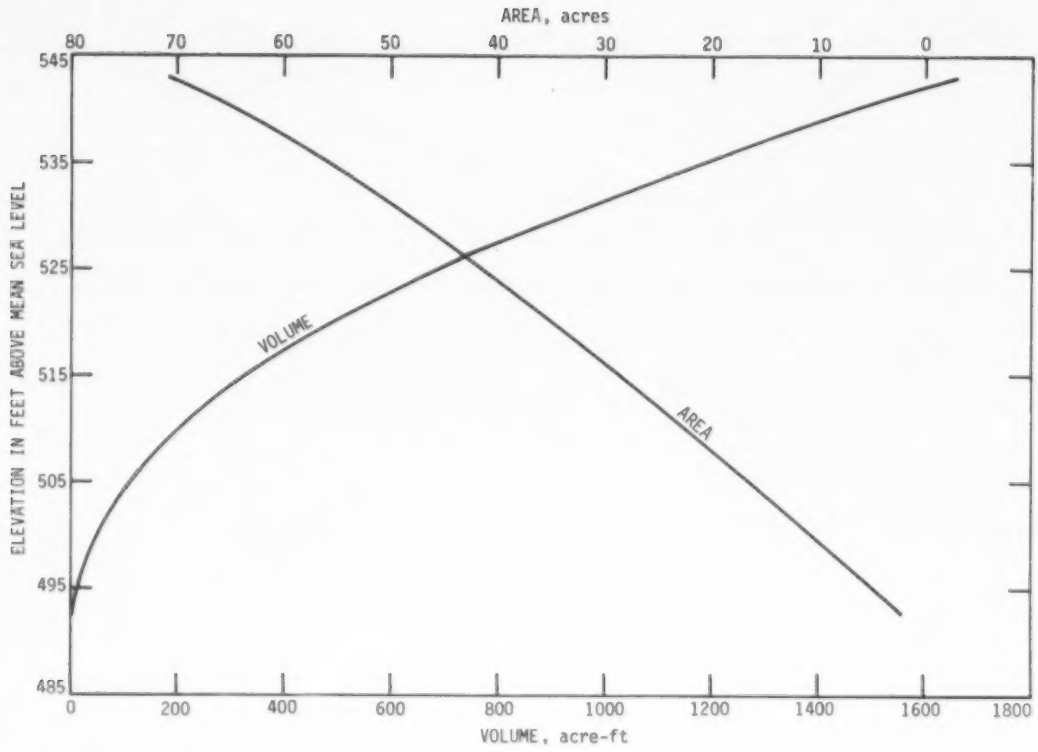

Figure 34. Stage-volume, stage-area curves for Coal City Area No. 1 lake.

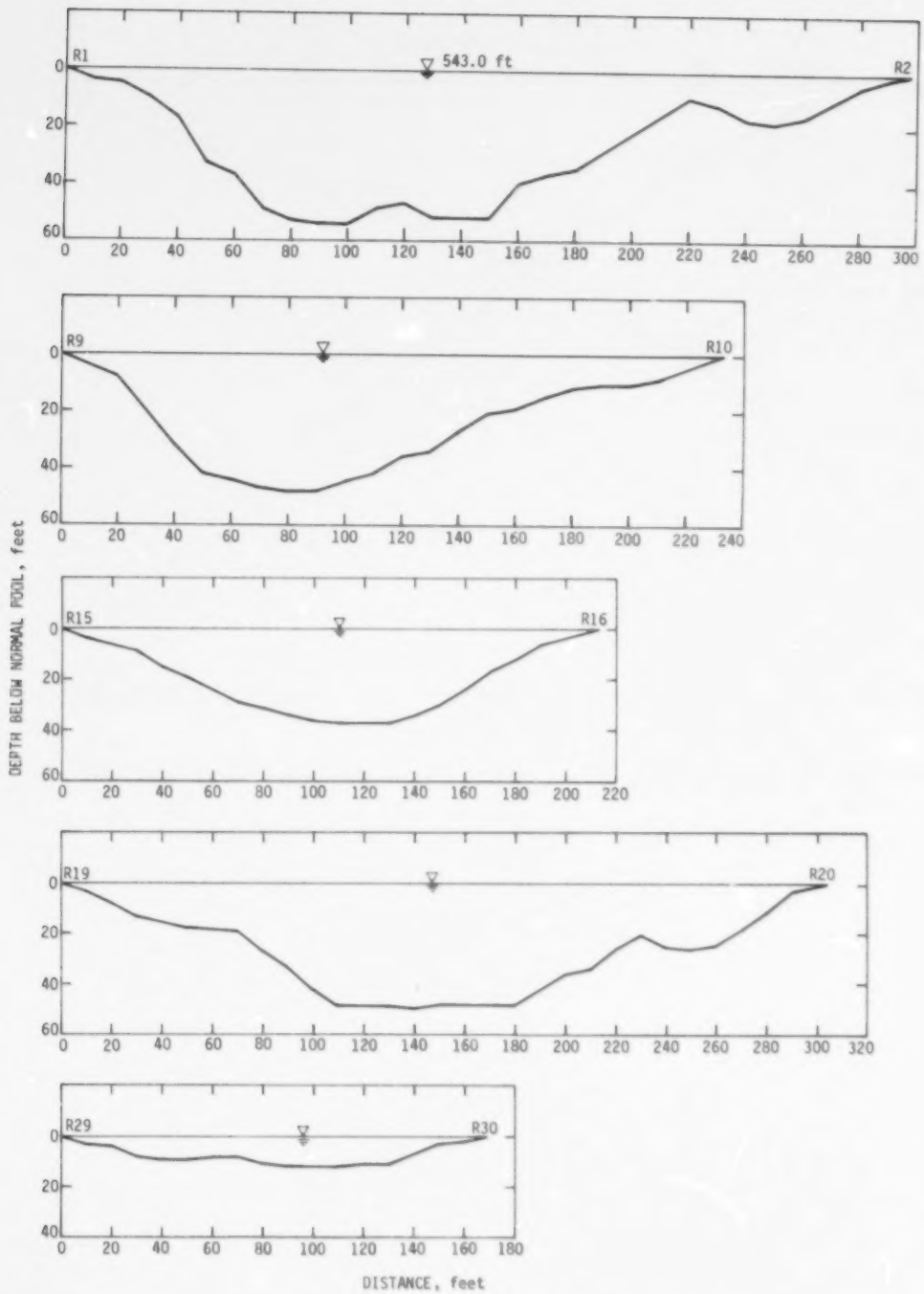

Figure 35. Representative cross sections of Coal City Area No. 1 lake.

Table 35. Chemical Analysis Data, Coal City Area No. 1 Lake

Depth	Temp	DO	Field pH	Field alk	Conductivity at 25°C	TDS	Hard	Cl	F	SO_4	NO_3-N
November 1977, 1 inch ice											
0	4.0	12.2	8.2	177		1208	733	16	0.15	577	0.21
2	4.2	12.1									
4	4.5	12.0									
6	4.8	11.8	8.2	177		1036	760	16	0.17	638	0.23
8	5.0	11.6									
10	5.0	11.4									
12	5.0	11.3	8.2	177		1078	773	16	0.16	615	0.26
February 1978, 10 inch ice											
0	0.5	15.7	8.4	174	1638	848	656	17	0.27	536	0.28
2	0.8	15.8			1663						
4	2.0	15.4			1700						
6	2.8	14.8	8.2	197	1826	920	684	20	0.27	575	0.34
8	3.2	13.2			1909						
10	3.8	11.8			1863						
12	4.0	10.8			1912						
13	4.2	9.6	7.9	212	1944	1075	770	18	0.27	692	0.31
April 1978											
0	12.5	9.6	8.1	172	1365	877	648	18	0.20	473	0.49
2	12.2	9.7			1386						
4	11.8	9.7			1353						
6	11.2	9.7			1357						
8	10.5	9.7	8.1	172	1367	876	648	17	0.20	477	0.51
10	10.0	9.7			1380						
12	9.9	9.7			1380						
14	9.9	9.6	8.0	177	1380	882	653	18	0.20	478	0.47

	November 1977			February 1978			April 1978		
	Surface	Middle	Bottom	Surface	Middle	Bottom	Surface	Middle	Bottom
Fe	0.16	0.41	0.31	0.01	0.04	0.40	0.08	0.11	0.09
Mn	0.09	0.08	0.09	0.02	0.05	0.26	0.05	0.06	0.06
Pb	0.04	0.05	0.05	0.14	0.13	0.14	ND	ND	ND
Cd	0.03	0.03	0.03	0.02	0.02	0.02	ND	ND	ND
Hg	0.53	0.40	0.29	0.25	0.32	0.41	0.11	0.09	0.56
K	5.2	5.5	5.5	4.2	4.3	5.0	5.4	5.4	5.5
Na	60	30	36	26	27	40	25	26	26
Cu	0.01	0.03	0.02	<0.01	0.02	0.02	0.01	0.02	0.02
Zn	0.02	0.05	0.05	0.01	0.08	0.07	ND	0.05	0.04
As	0.001	0.001	0.001	<0.002	<0.002	<0.002	0.001	<0.001	<0.001
Se	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Ag	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cr	ND	ND	ND	ND	ND	ND	ND	ND	ND
Ba	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
B	0.3	0.3	0.4	0.3	0.3	0.4	0.3	0.3	0.3

Note: Temperature, °Celsius; conductivity, μ mhos; Hg, μg/l; all other values except pH, mg/l

11 -- Clear Lake

Clear Lake is located in Section 5, T31N, R9E, Kankakee County. The lake and surrounding property now is owned by the South Wilmington Sportsman Club. The mine was opened by Peabody Coal Company in September 1950 and closed in July 1963. The Colchester (No. 2) coal was mined with a Page 10 cubic yard dragline. The coal was overlain by less than 50 feet of overburden of which 20 to 30 feet was sand and sandy clay. The rock overburden consisted of the Francis Creek shale (15).

The general shape of the lake and locations of range lines where depth measurements were taken are shown in figure 36. The area and volume of the lake at elevation 590 feet above mean sea level are 15.37 acres and 473 acre-feet, respectively. Stage-volume and stage-area curves for the lake are presented in figure 37. The maximum measured and calculated average depths are 53 and 30.8 feet, respectively. Representative cross sections illustrating the general lake profile are shown in figure 38.

The watershed of this lake is extremely limited to the immediate area. It covers some 32 acres of which about 1/3 is strip mine spoil. The remaining 20 acres is farm land and park area covered with pine trees. A curve number (CN) value of 70 was selected for runoff calculations because of the high percentage of farm land in the watershed. Precipitation data from Kankakee were used for the selected 20 years of simulated runoff.

On the basis of the calculated net runoff values and a groundwater contribution of 0.036 gpm/ft x 2250 ft (the approximate length of the lake), the estimated yields presented in table 36 were determined.

Chemical analysis data for water samples collected November 1977 and February and April 1978 are presented in table 37.

Table 36. Estimated Yield Potential of Clear Lake

	Yield (mgd) for given recurrence interval (yr)			
	1.1	*2*	*5*	*10*
Net surface yield	0.01	0.03	0.04	0.05
Groundwater contribution	0.12	0.12	0.12	0.12
Total	0.13	0.15	0.16	0.17

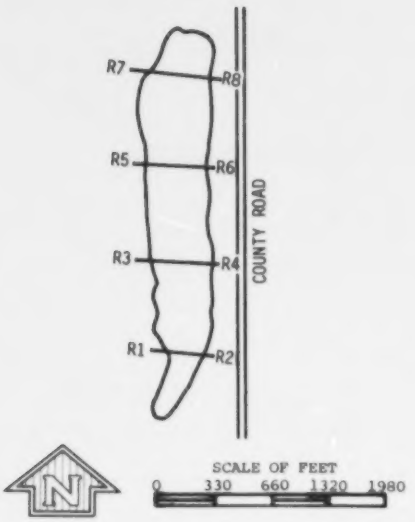

Figure 36. Clear lake range lines.

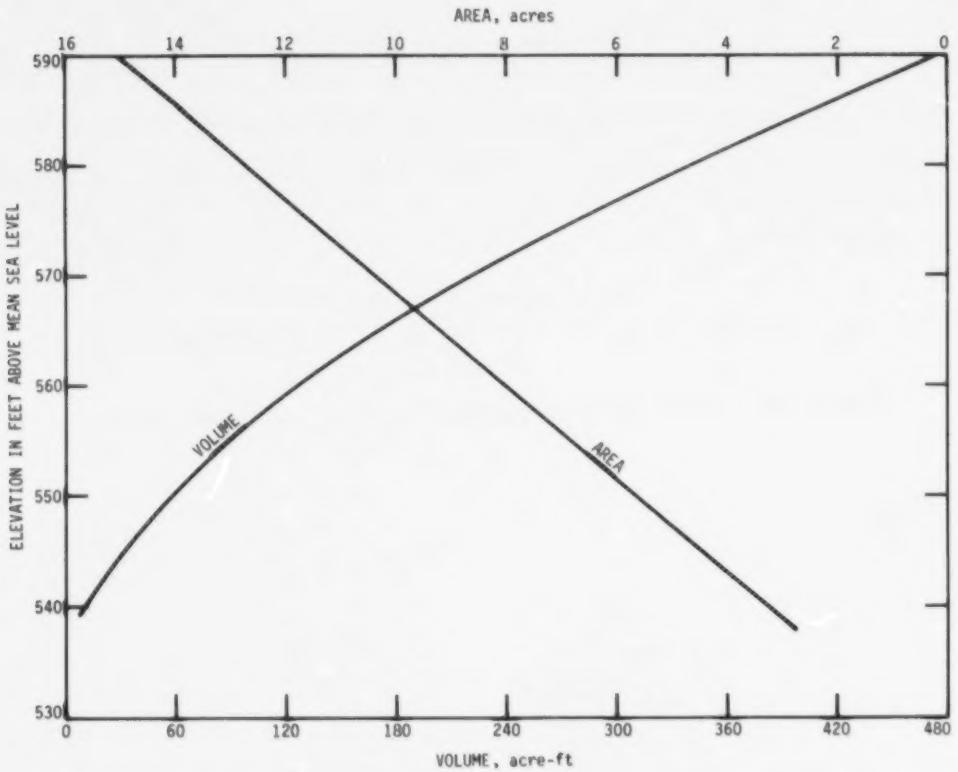

Figure 37. Stage-volume, stage-area curves for Clear lake.

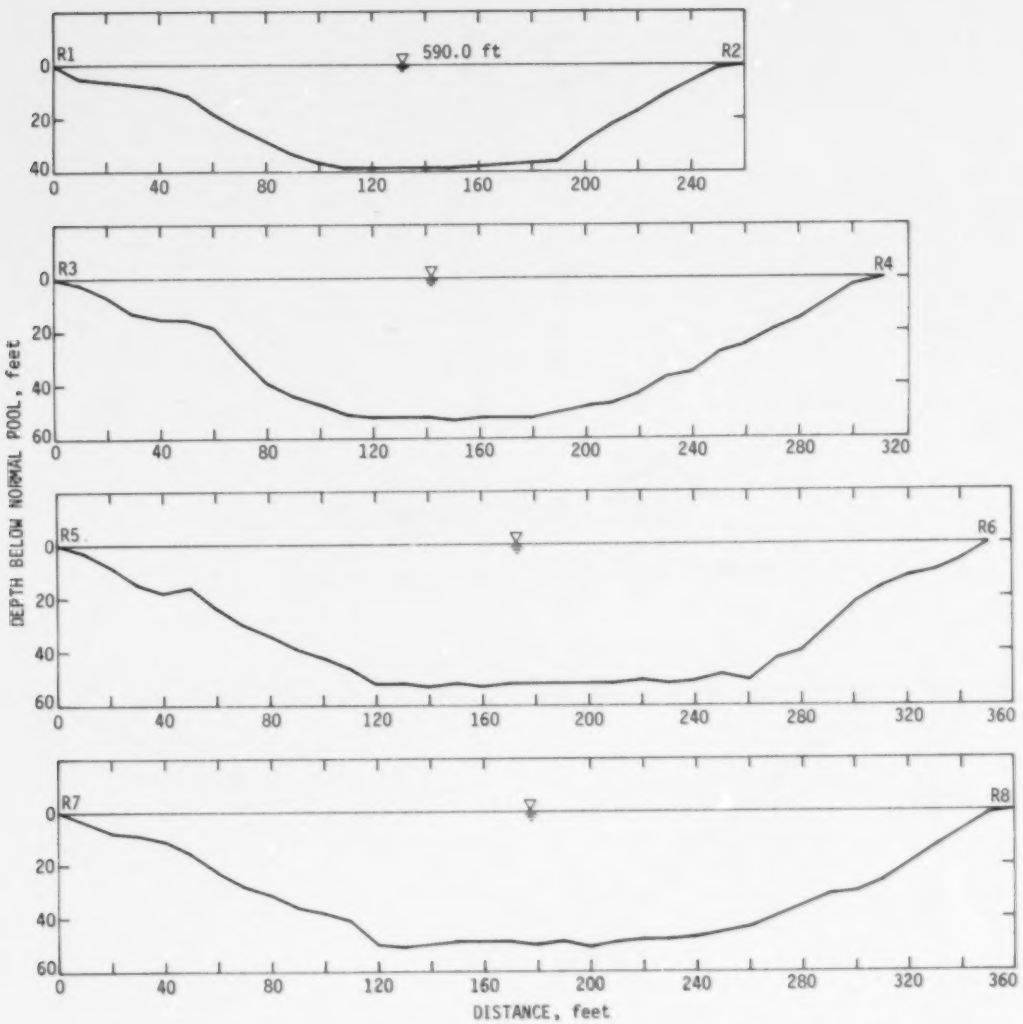

Figure 38. Representative cross sections of Clear lake.

Table 37. Chemical Analysis Data, Clear Lake

Depth	Temp	DO	Field pH	Field alk	Conductivity at 25°C	TDS	Hard	Cl	F	SO_4	NO_3-N
November 1977											
0	5.5	12.2	8.3	114		424	327	3	0.19	188	0.15
5	5.5	12.0									
10	5.5	11.5									
15	5.5	11.4									
20	5.5	10.8									
25	5.5	9.8	8.3	114		462	387	2	0.19	186	0.13
30	5.5	9.6									
35	5.5	9.6									
40	5.5	9.5									
45	5.5	9.4									
50	5.5	8.7	8.3	116		436	380	3	0.19	185	0.17
February 1978, 6 inch ice											
0	0.0	9.8	8.1	114	567	316	288	4.9	0.24	134	0.29
5	2.0	13.7			680						
10	2.2	14.2			688						
15	2.8	13.8			681						
20	3.0	13.8			681						
25	3.0	13.8	8.4	121	689	440	350	3.9	0.24	242	0.14
30	3.2	13.6			689						
35	3.8	12.4			697						
40	4.0	11.3			712						
42	4.2	10.0	8.3	126	721	447	370	3.9	0.22	234	0.15
April 1978											
0	11.8	9.9	8.4	90	601	380	300	3	0.2	198	0.31
5	11.5	9.9			612						
10	11.5	10.0			612						
15	10.2	9.9			635						
20	7.2	10.0			656						
25	6.0	10.2	8.0	120	681	431	340	3	0.2	224	0.27
30	6.0	10.3			689						
35	5.5	10.4			713						
40	5.5	9.6			716						
45	5.5	9.2			729						
50	5.5	6.2	7.8	120	767	458	358	3	0.2	233	0.36

	November 1977			February 1978			April 1978		
	Surface	Middle	Bottom	Surface	Middle	Bottom	Surface	Middle	Bottom
Fe	0.15	0.19	0.44	0.05	0.02	<0.01	0.15	0.07	0.08
Mn	0.03	0.02	0.03	0.06	0.02	0.02	0.03	0.02	0.02
Pb	0.05	0.05	0.04	0.07	0.11	0.11	ND	ND	ND
Cd	ND	ND	<0.01	0.01	0.01	0.01	ND	ND	ND
Hg	0.82	0.88	0.75	0.12	0.18	0.16	0.10	0.16	0.11
K	2.8	2.8	2.7	2.0	2.8	2.7	3	3.3	3.3
Na	10	10	8	11	12	13	9	11	12
Cu	<0.01	0.02	0.02	<0.01	0.02	0.01	ND	0.02	0.01
Zn	0.02	0.06	0.05	<0.01	0.03	0.01	ND	0.02	0.02
As	<0.001	<0.001	0.001	<0.002	<0.002	<0.002	<0.001	<0.001	<0.001
Se	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Ag	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cr	ND	ND	ND	ND	ND	ND	ND	ND	ND
Ba	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
B	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2

Note: Temperature, °Celsius; conductivity, μ mhos; Hg, μg/l; all other values except pH, mg/l

12 -- Northern Pit No. 14

Northern Pit No. 14 is located in Section 13, T31N, R8E, Grundy County. The lake and surrounding property are owned by Peabody Coal Company who opened the mine in September 1969 and closed it in November 1973. The Summum (No. 4) coal was mined with a 7800 Marion 30 cubic yard dragline. The coal was overlain by 50 to 75 feet of overburden of which almost all was glacial drift. These materials consisted predominately of clay and sandy clay (15).

The general shape of the lake and locations of range lines where depth measurements were taken are shown in figure 39. The area and volume of the lake at 576 feet above mean sea level are 17.45 acres and 473 acre-feet, respectively. Stage-volume and stage-area curves for the lake are presented in figure 40. The maximum measured and calculated average depths of the lake are 65 and 27.1 feet, respectively. Representative cross sections illustrating the general lake profile are shown in figure 41.

The watershed of this lake consists of about 2/3 of the total spoil area from this mine and covers approximately 128 acres. The entire watershed is planted in clover and grass. A curve number (CN) value of 60 was selected for runoff calculations since this watershed is similar to that for Middle Grove. Precipitation data from Kankakee were used for the selected 20 years of simulated runoff.

On the basis of the calculated net runoff values and a groundwater contribution of 0.036 gpm/ft x 4200 ft (the approximate total length of the various portions of the lake), the estimated yields presented in table 38 were determined.

Chemical analysis data for water samples collected December 1977 and February and April 1978 are presented in table 39.

Table 38. Estimated Yield Potential of Northern Pit No. 14

	Yield (mgd) for given recurrence interval (yr)			
	1.1	*2*	*5*	*10*
Net surface yield	0.03	0.07	0.11	0.12
Groundwater contribution	0.22	0.22	0.22	0.22
Total	0.25	0.29	0.33	0.34

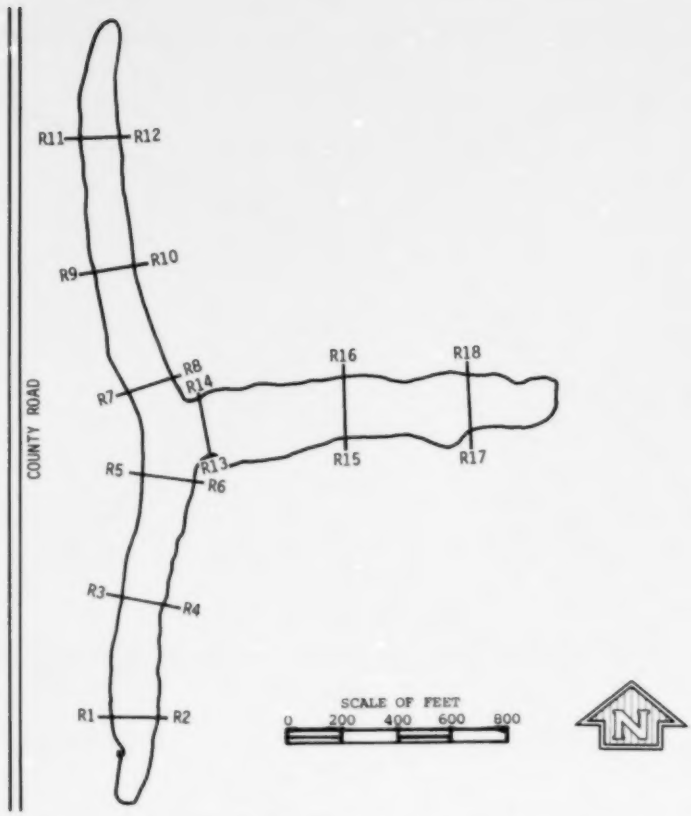

Figure 39. Northern Pit No. 14 and range lines.

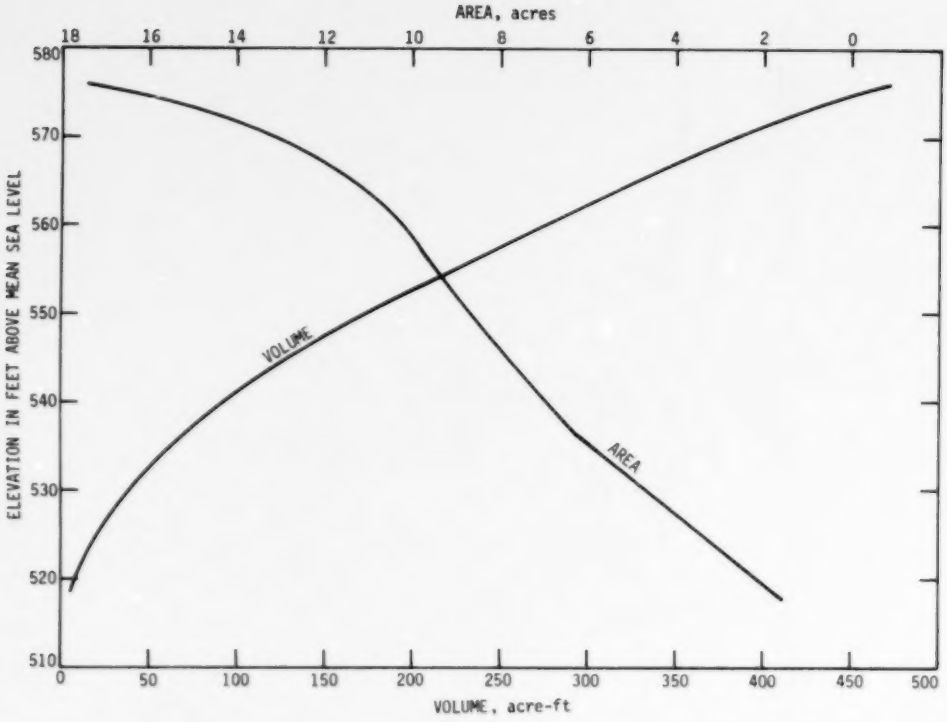

Figure 40. Stage-volume, stage-area curves for Northern Pit No. 14.

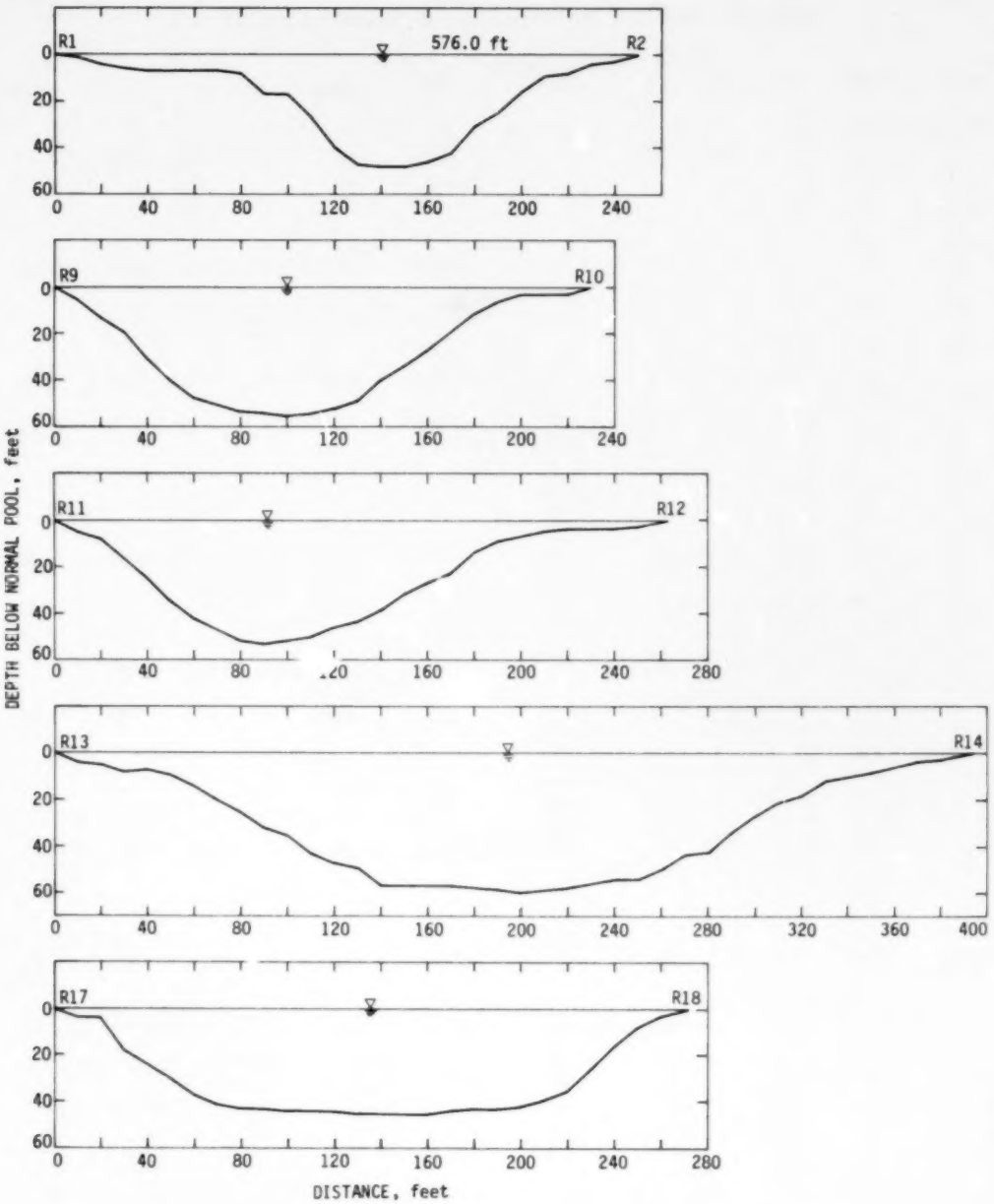

Figure 41. Representative cross sections of Northern Pit No. 14.

Table 39. Chemical Analysis Data, Northern Pit No. 14

Depth	Temp	DO	Field pH	Field alk	Conductivity at 25°C	TDS	Hard	Cl	F	SO_4	NO_3-N
November 1977											
0	4.5	11.2	8.2	76		1552	1107	7	0.41	1040	0.37
5	4.5	11.6									
10	4.5	11.6									
15	4.5	11.6									
25	4.5	11.6									
30	4.5	11.3	8.1	76		1590	1113	6	0.42	1088	0.28
35	4.5	11.2									
40	4.5	11.0									
45	4.5	11.0									
55	4.5	10.8									
58	4.5	9.0	8.0	76		1600	1080	7	0.42	1077	0.36
February 1978											
0	0.0	16.4	8.0	83	2700	1616	1090	8	0.44	1213	0.37
5	1.5	16.4			2666						
10	1.5	16.4			2718						
15	1.5	16.4			2718						
20	1.5	16.4			2718						
25	1.5	16.4			2752						
35	1.8	16.2	8.0	83	2720	1624	1070	8	0.46	1163	0.28
40	2.0	16.1			2720						
50	2.0	15.5			2754						
55	2.5	14.8			2822						
60	3.2	12.5			2955						
65	4.0	2.4	7.0	134	4212	1998	1170	13	0.48	1334	0.36
April 1978											
0	9.5	10.3	8.0	64	1750	1485	990	8	0.4	973	0.58
5	9.1	10.3			1832						
10	8.9	10.3			1832						
15	8.7	10.3			1832						
20	8.6	10.3			1858						
25	8.5	10.3			1872						
35	8.5	10.3	8.0	69	1872	1479	990	7	0.4	971	0.53
40	8.4	10.3			1872						
50	7.8	10.1			1898						
55	6.0	10.7			1928						
60	5.6	10.5			2000						
65	6.1	0.5	7.7	80	4284	1519	1010	8	0.4	997	0.44

	November 1977			February 1978			April 1978		
	Surface	Middle	Bottom	Surface	Middle	Bottom	Surface	Middle	Bottom
Fe	0.13	0.96	0.19	0.04	0.01	2.51	0.16	0.19	0.16
Mn	0.05	0.28	0.06	0.08	0.05	0.38	0.04	0.05	0.07
Pb	0.08	0.07	0.06	0.17	0.17	0.17	ND	ND	ND
Cd	0.03	0.04	0.04	0.02	0.02	0.02	ND	ND	ND
Hg	0.76	0.56	0.48	0.19	0.31	0.19	0.17	0.20	0.10
K	6.4	6.6	5.8	6	6	8	7.6	7.8	7.9
Na	54	54	52	62	62	120	52	53	57
Cu	0.01	0.03	0.02	0.01	0.01	0.02	0.01	0.02	0.02
Zn	0.02	0.06	0.05	0.02	0.04	0.07	ND	0.05	0.04
As	<0.001	<0.001	<0.001	<0.002	<0.002	<0.002	<0.001	<0.001	<0.001
Se	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Ag	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cr	ND	ND	ND	ND	ND	ND	ND	ND	ND
Ba	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
B	0.3	0.3	0.3	0.3	0.3	0.5	0.3	0.3	0.3

Note: Temperature, °Celsius; conductivity, μ mhos; Hg, μg/l; all other values except pH, mg/l

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